… for a brighter future

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

Center for Energy, Environmental, and Economic Systems Analysis (CEEESA)
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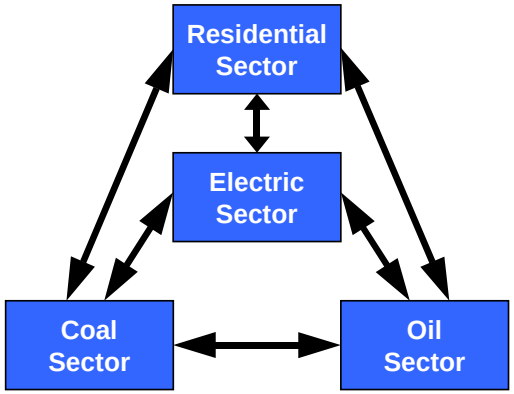
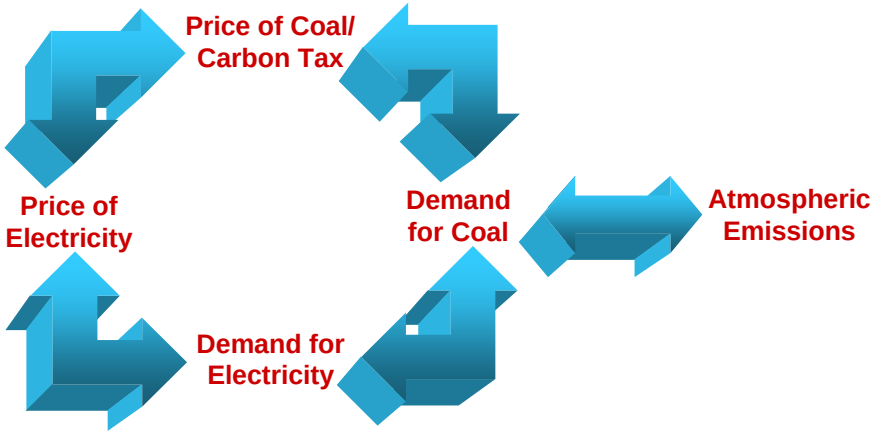
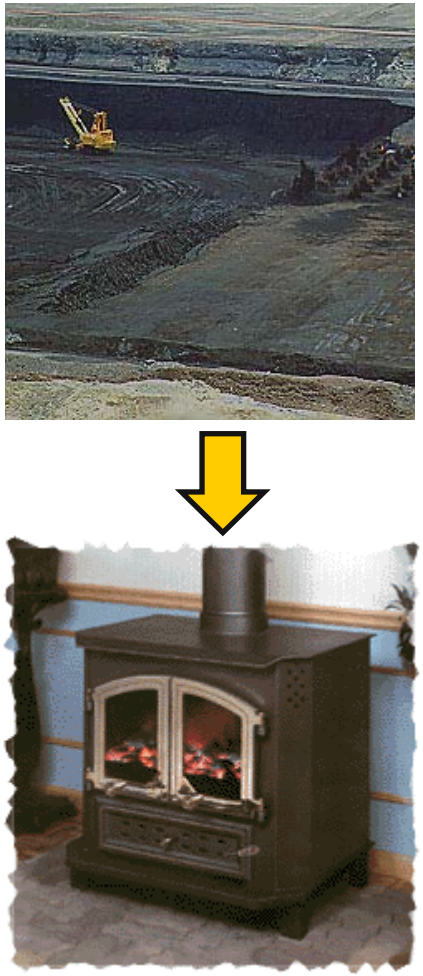
A U.S. Department of Energy laboratory
managed by UChicago Argonne, LLC

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





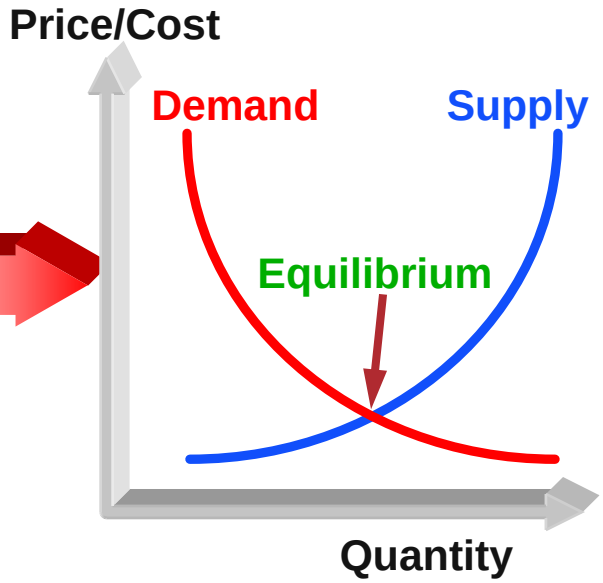


ENPEP-BALANCE Determines the Equilibrium Supply/Demand Balance of the Energy System

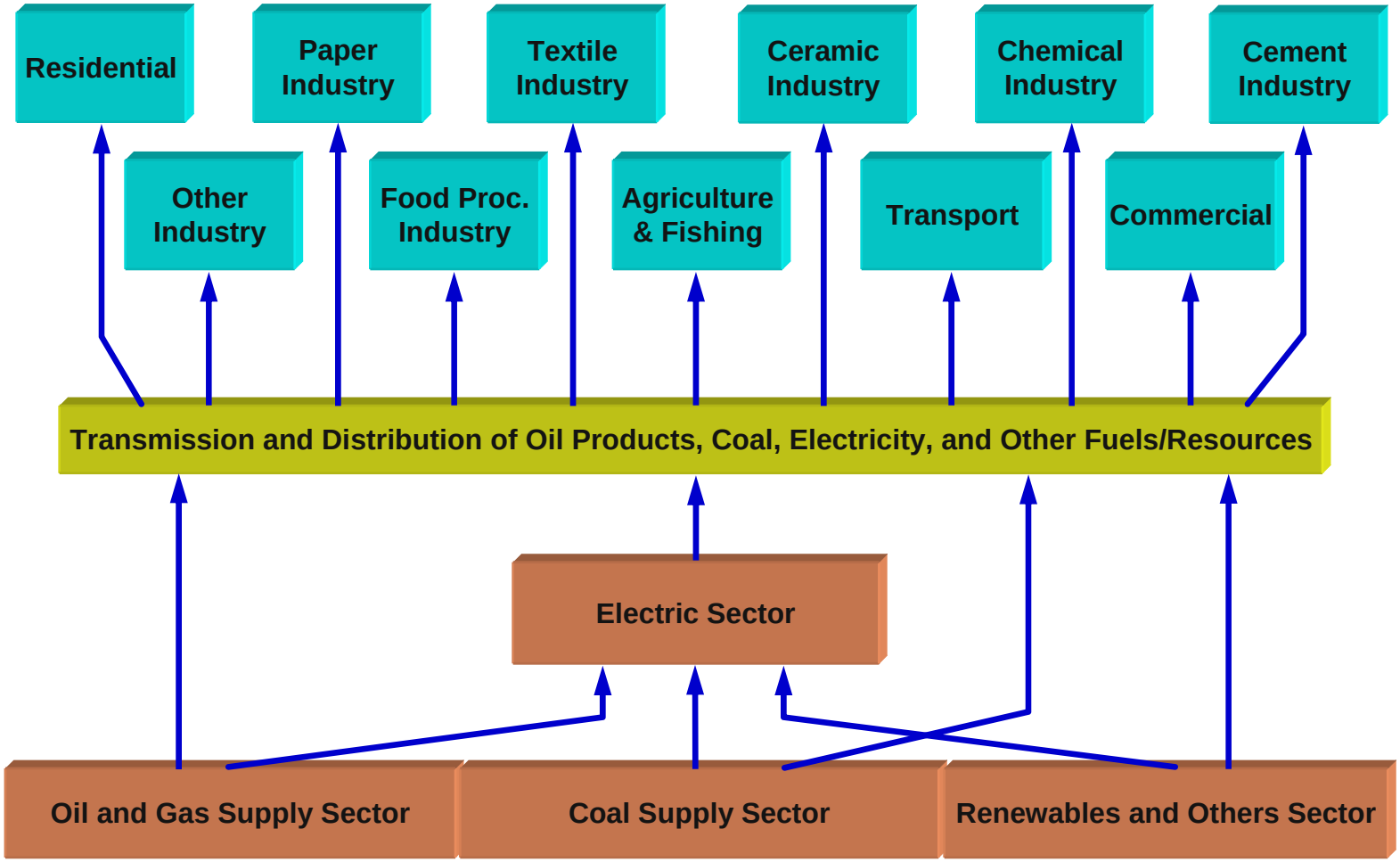
INPUT

- Energy system structure
- Base-year energy flows and prices
- Energy demand growth projections
- Technical and policy constraints

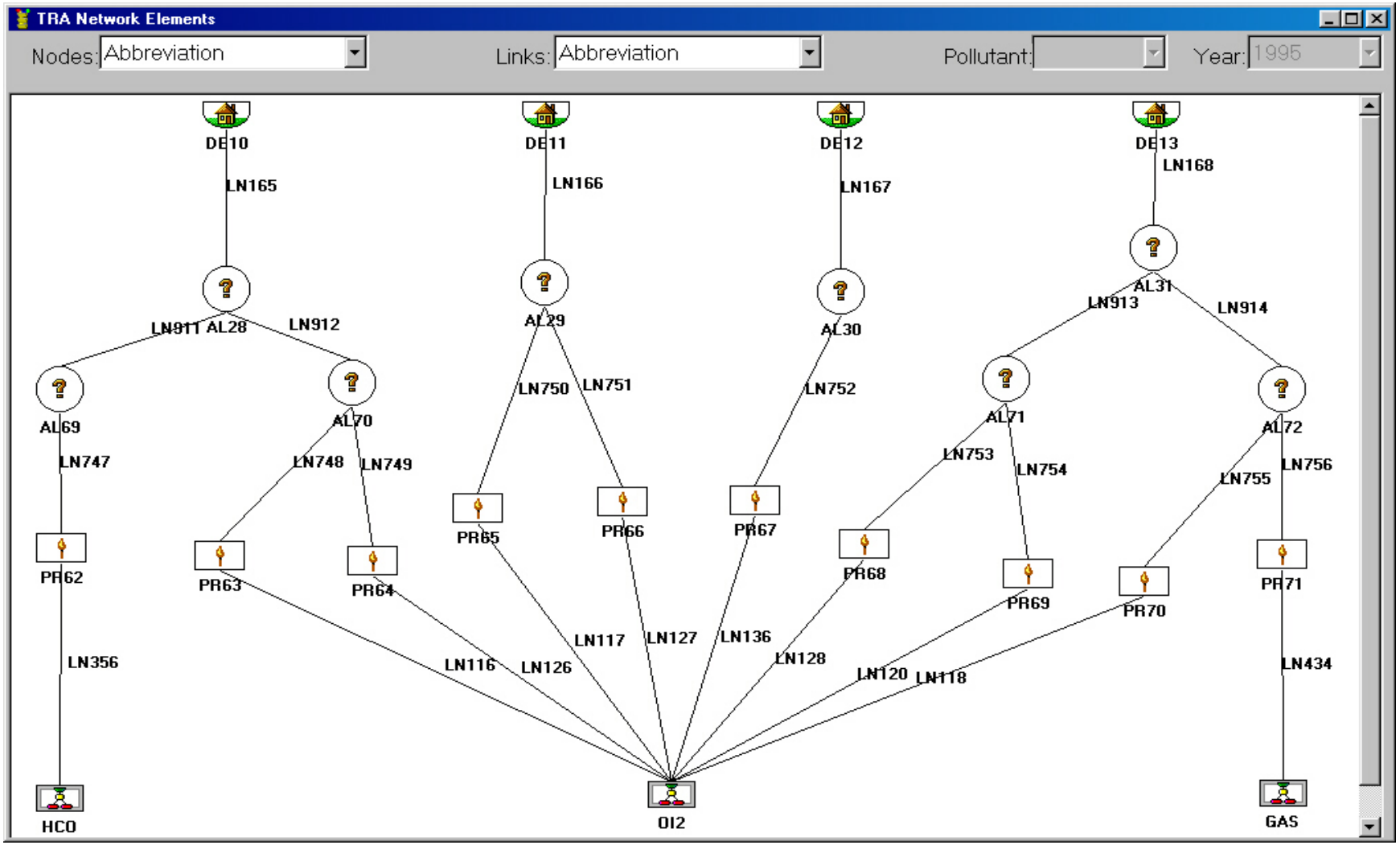
OUTPUT



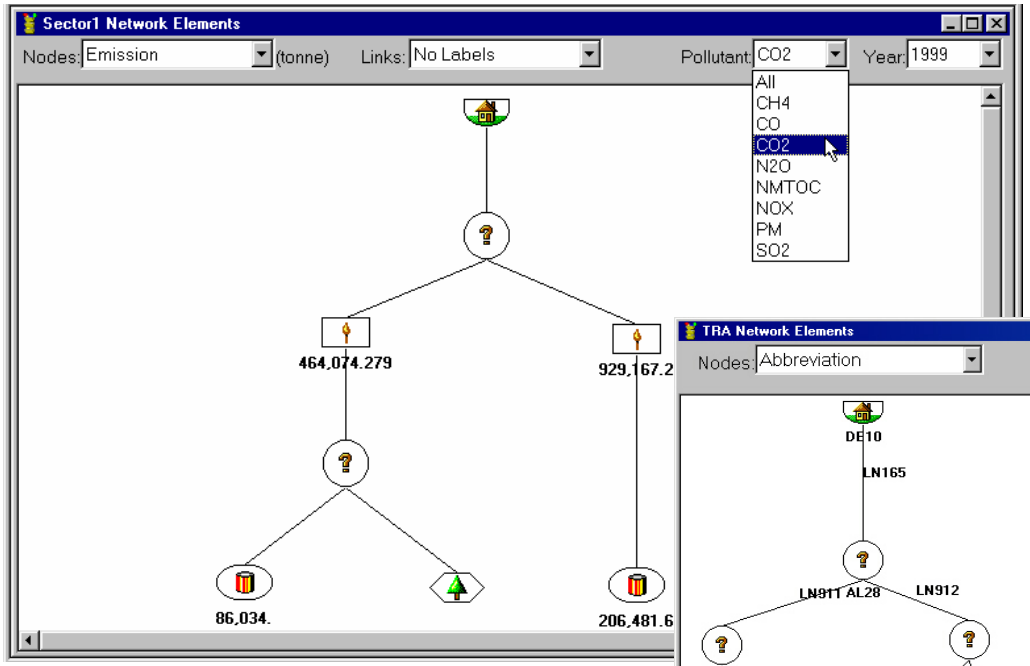
ENPEP-BALANCE Uses an Energy Network to Simulate Energy Markets

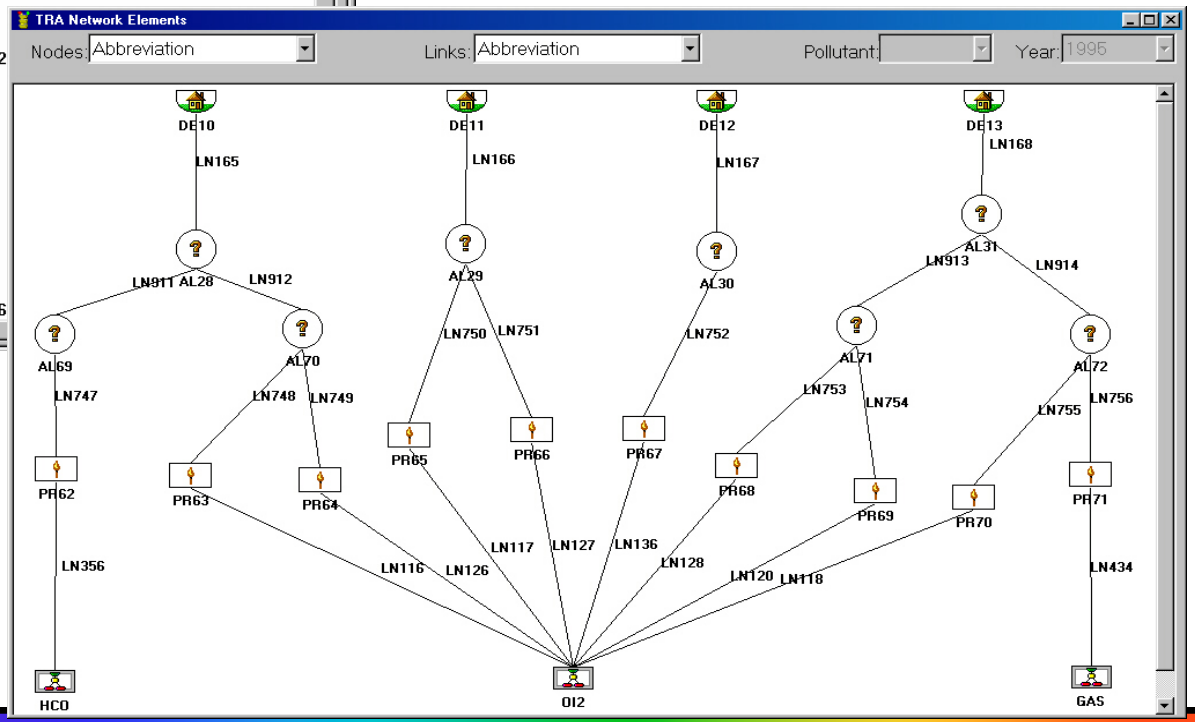


Networks Consist of Nodes and Links



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

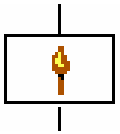




The Following Node Types Are Available to Model Different Energy Activities

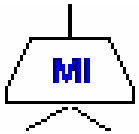
- Demand

- Conversion Processes

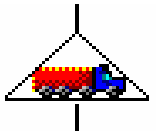


Single In-/Output

Multi Output



Multi Input



Transport

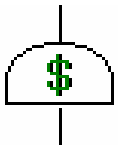
- Resource Processes

Depletable

Renewable

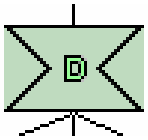
- Economic Processes

Decision/Allocation



Pricing

- Electricity Dispatch and Thermal and Hydro Units

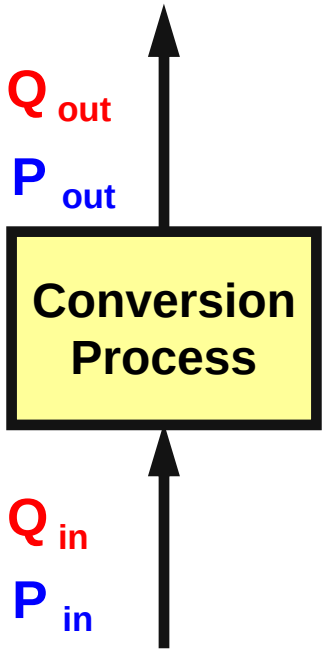


Central Dispatch

Thermal Unit

Hydro Unit

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



- **$Quantity_{output} = f(Quantity_{input})$**
  - Example conversion process

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

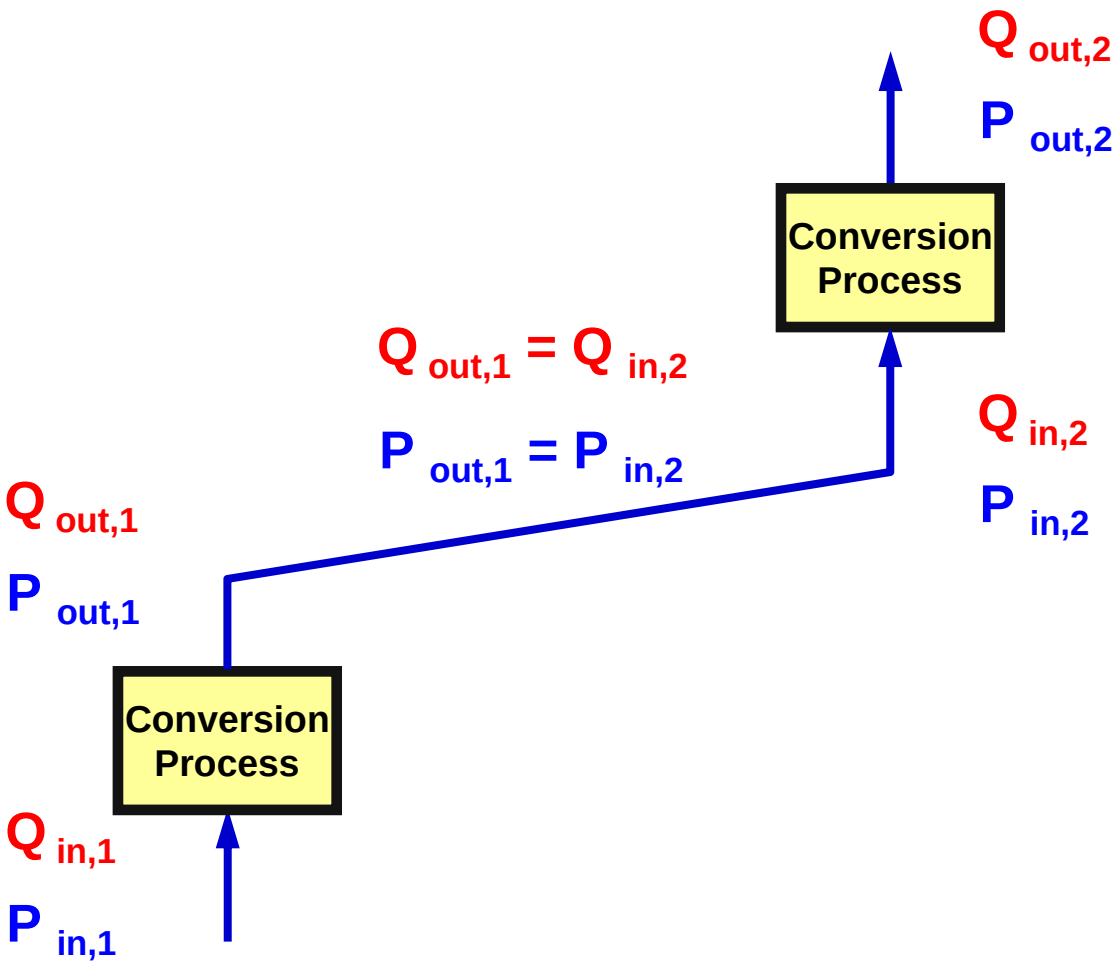
    E: conversion efficiency

- **$Price_{output} = f(Price_{input})$**
  - Example conversion process

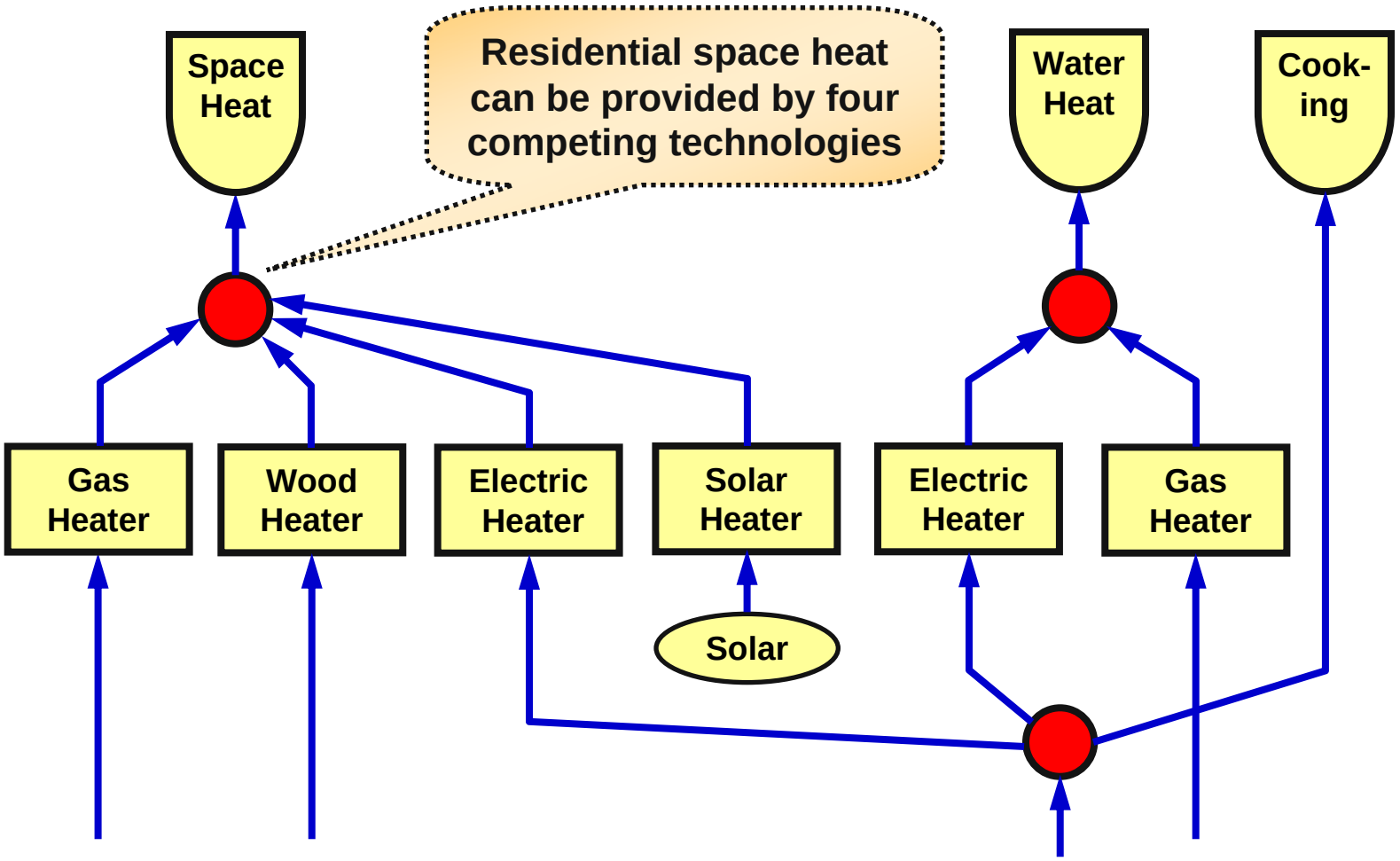
    Revenue = Cost

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

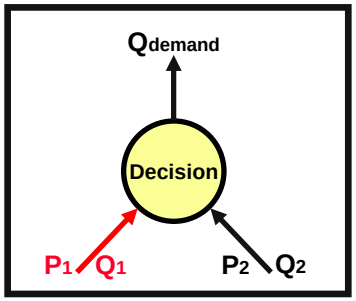
The Links Connect the Nodes and Pass Information from One Node to Another



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

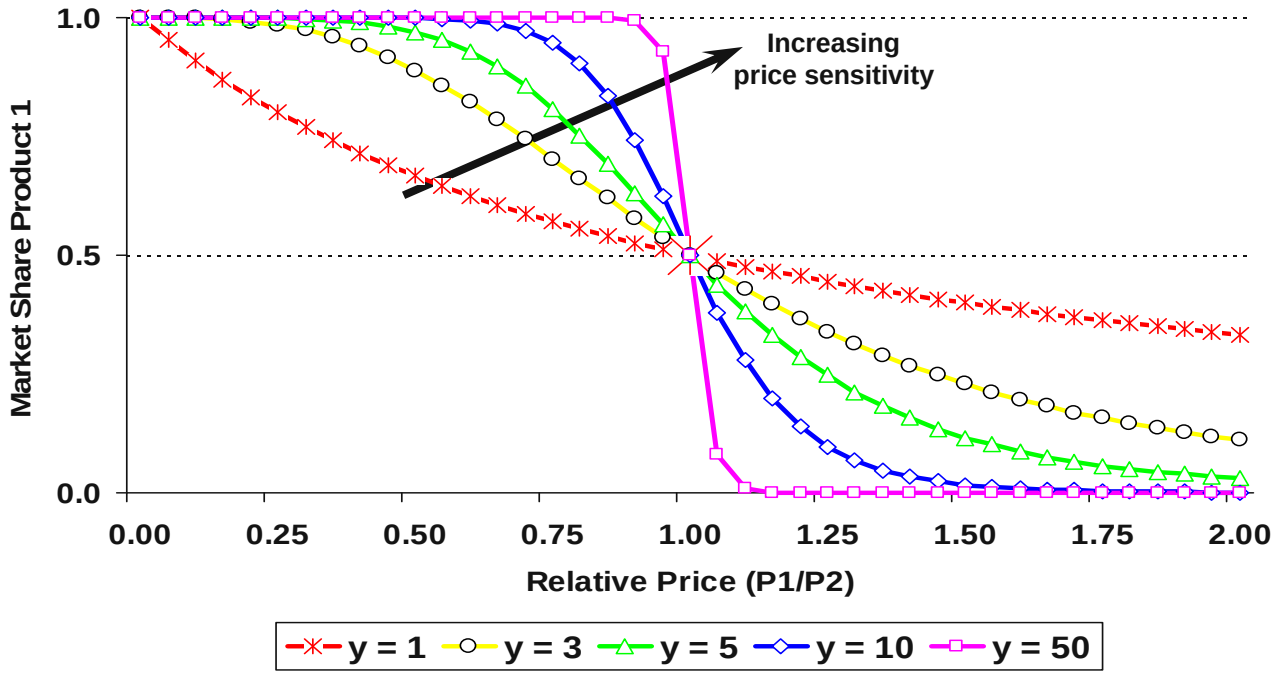


ENPEP-BALANCE Uses a Logit-Function to Estimate Market Shares of Competing Commodities at the Decision Node



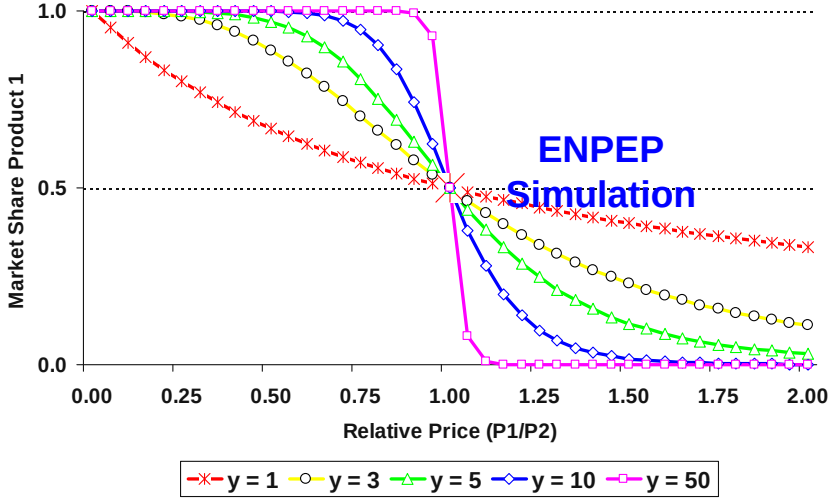
$$MS_1 = \frac{Q_1}{Q_1 + Q_2} = \frac{\left[\frac{1}{P_1 \times PM_1}\right]^{\gamma}}{\left[\frac{1}{P_1 \times PM_1}\right]^{\gamma} + \left[\frac{1}{P_2 \times PM_2}\right]^{\gamma}}$$

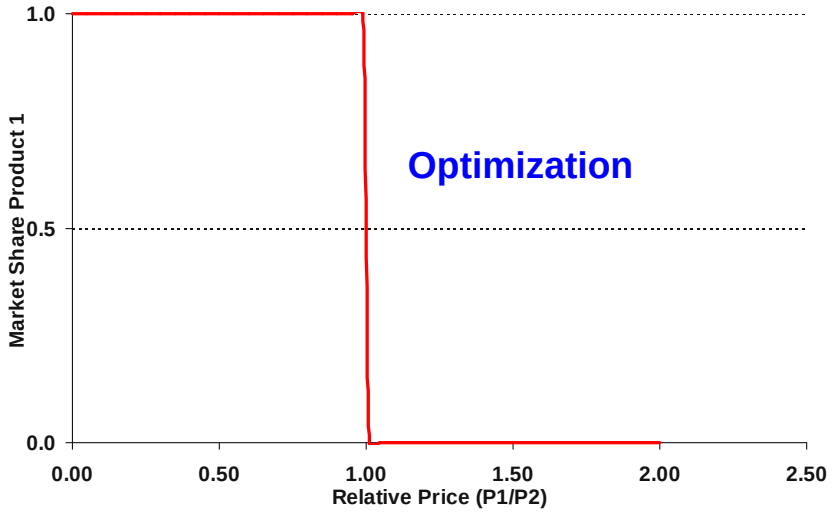
- γ: price sensitivity for this decision process
- MS: market share
- P: price
- PM: premium multiplier
- Q: quantity



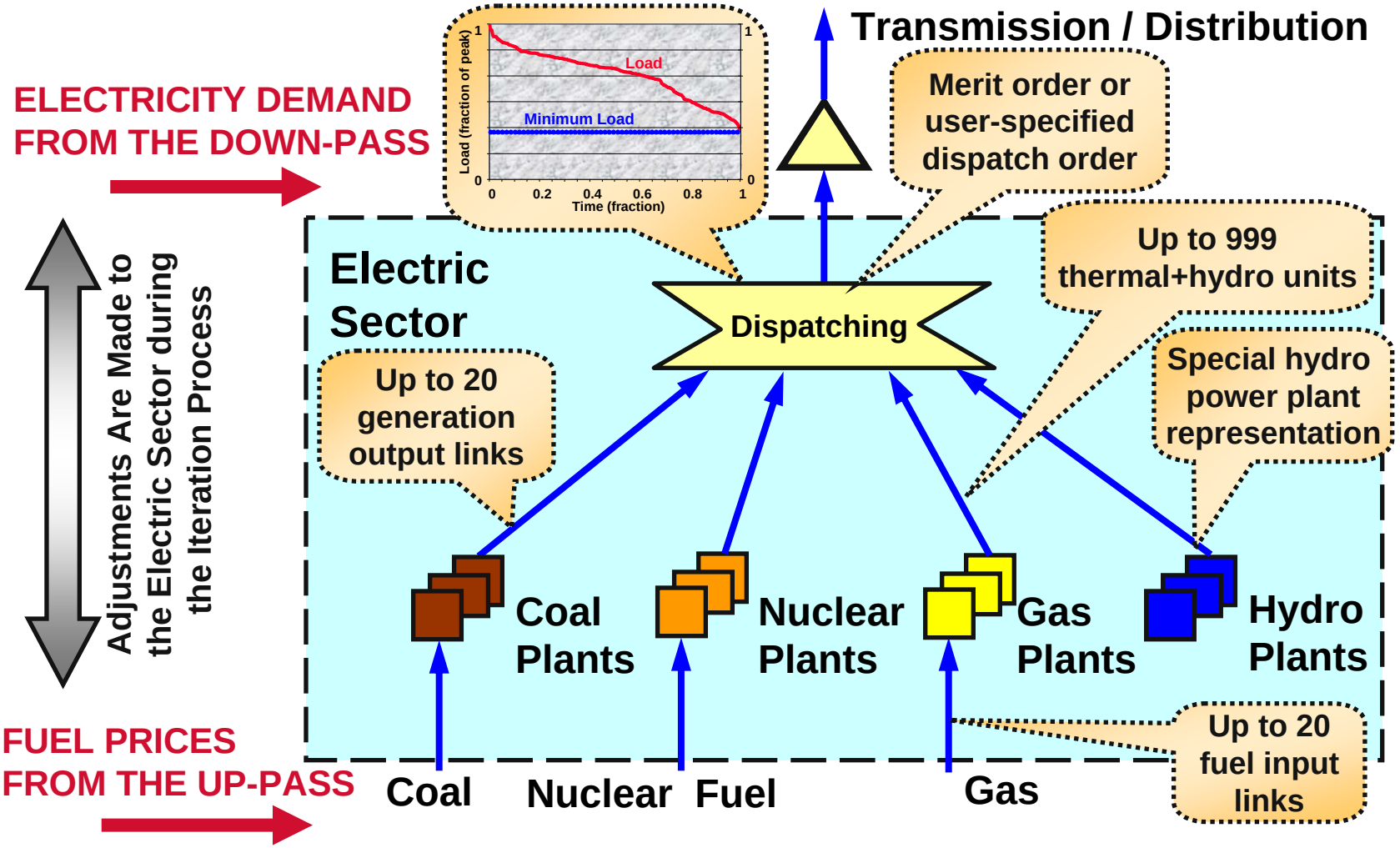
The ENPEP-BALANCE Nonlinear Equilibrium Algorithm Is Based on Decentralized Decision Making

- 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

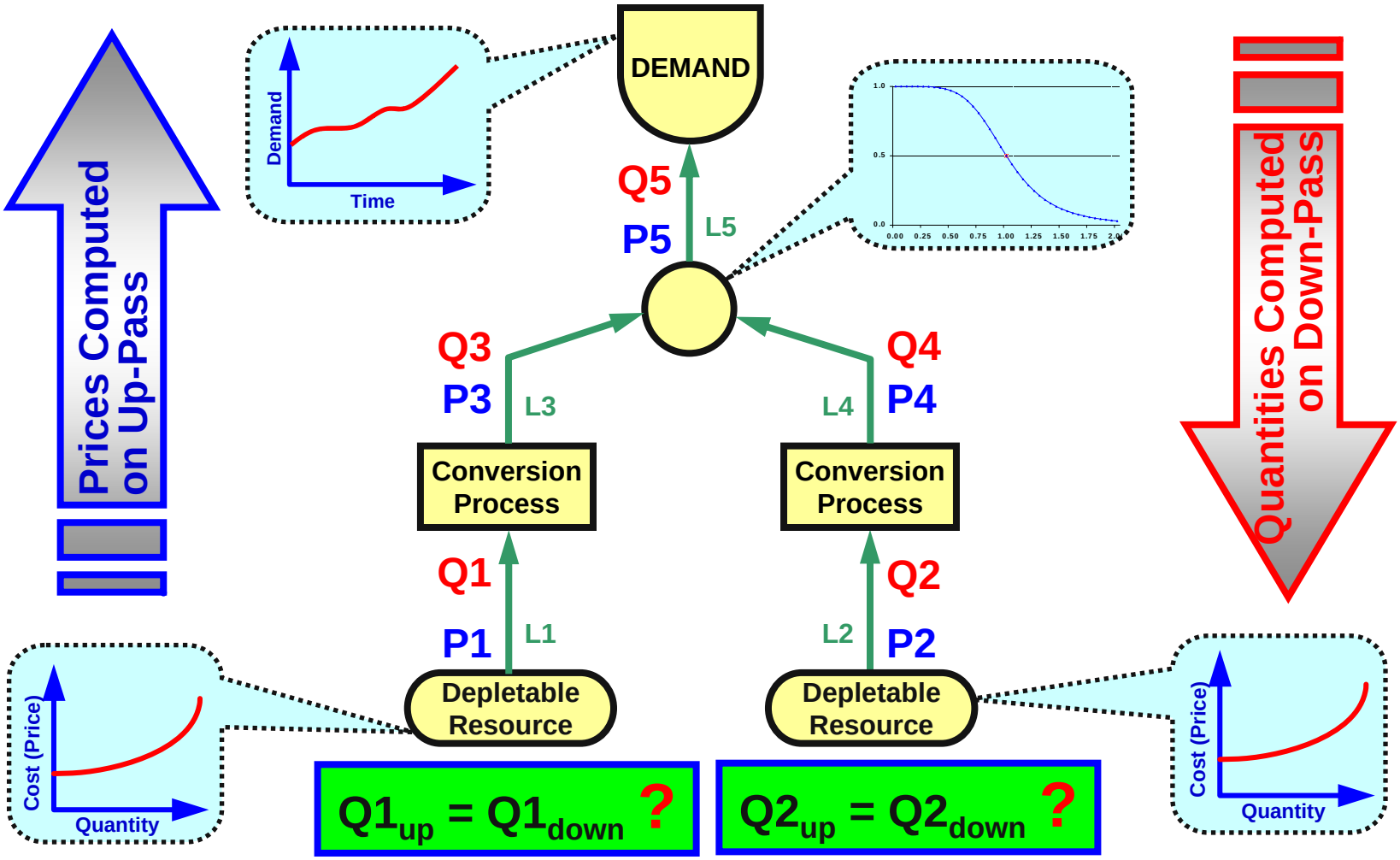




The Electricity Dispatch Node Handles the Electric Sector in a Special Way *(more details on electricity in separate lecture)*



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)

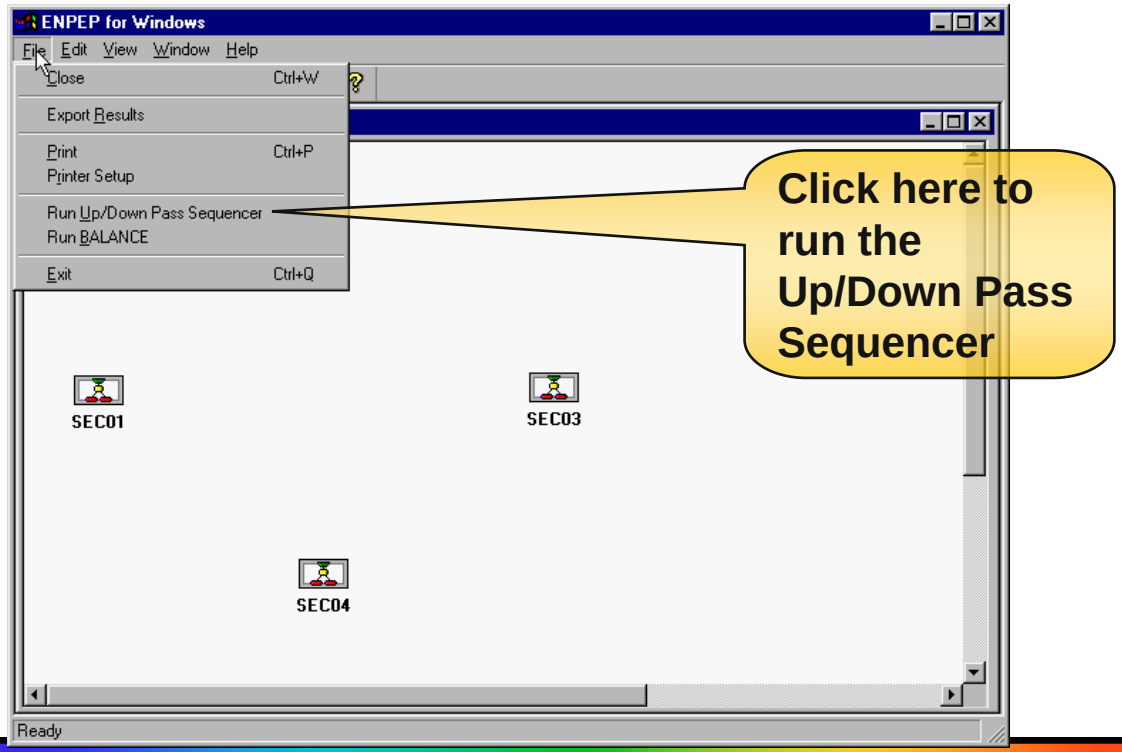


The Up-Pass and Down-Pass Tell the Model in Which Sequence to Perform the Calculations (Which Node Comes When)

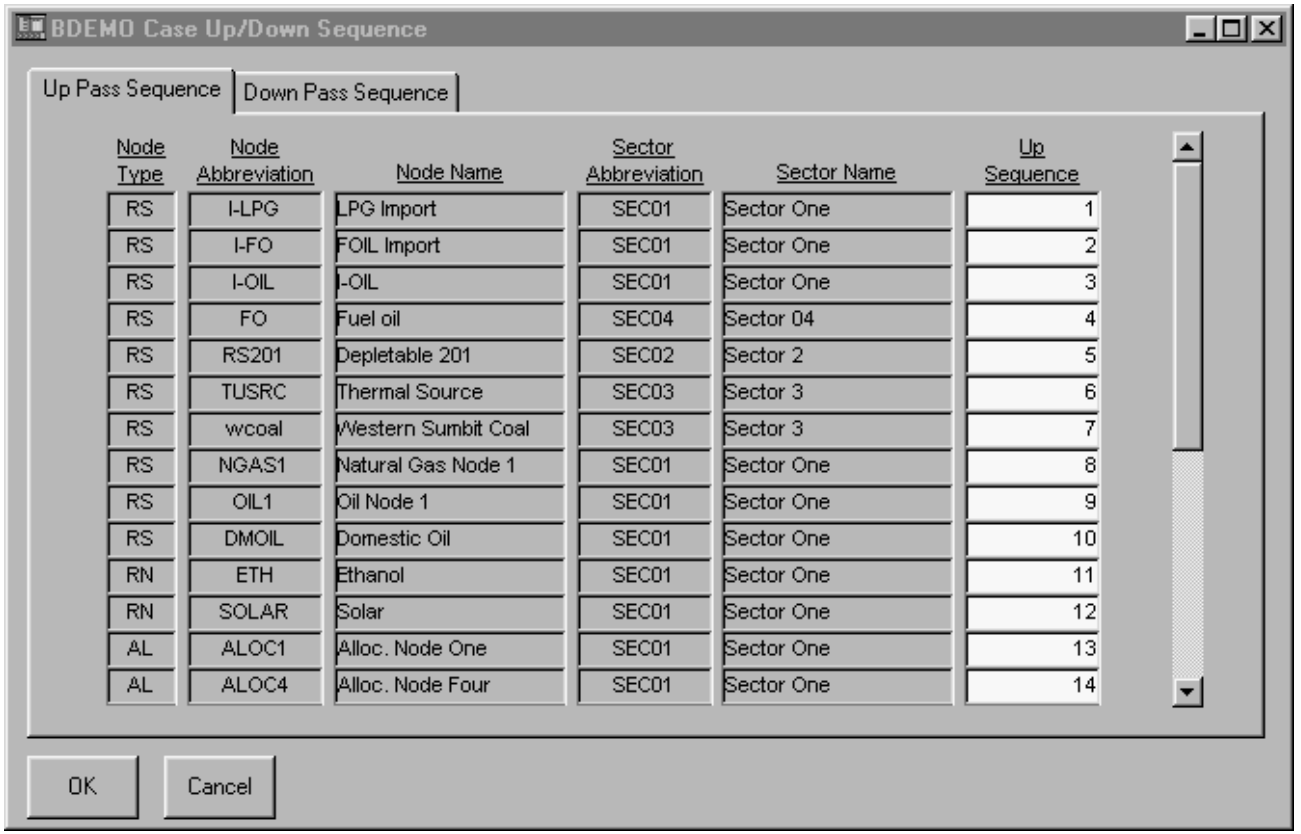
- Up-pass and down-pass sequences are repeated until convergence is achieved
- **CONVERGENCE IS ACHIEVED WHEN:**
  - Q1 (down) = Q1 (up) +/- Tolerance Level
  - Q2 (down) = Q2 (up) +/- Tolerance Level
  - The final result is a converged solution
  - The solution is in equilibrium across the whole network

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



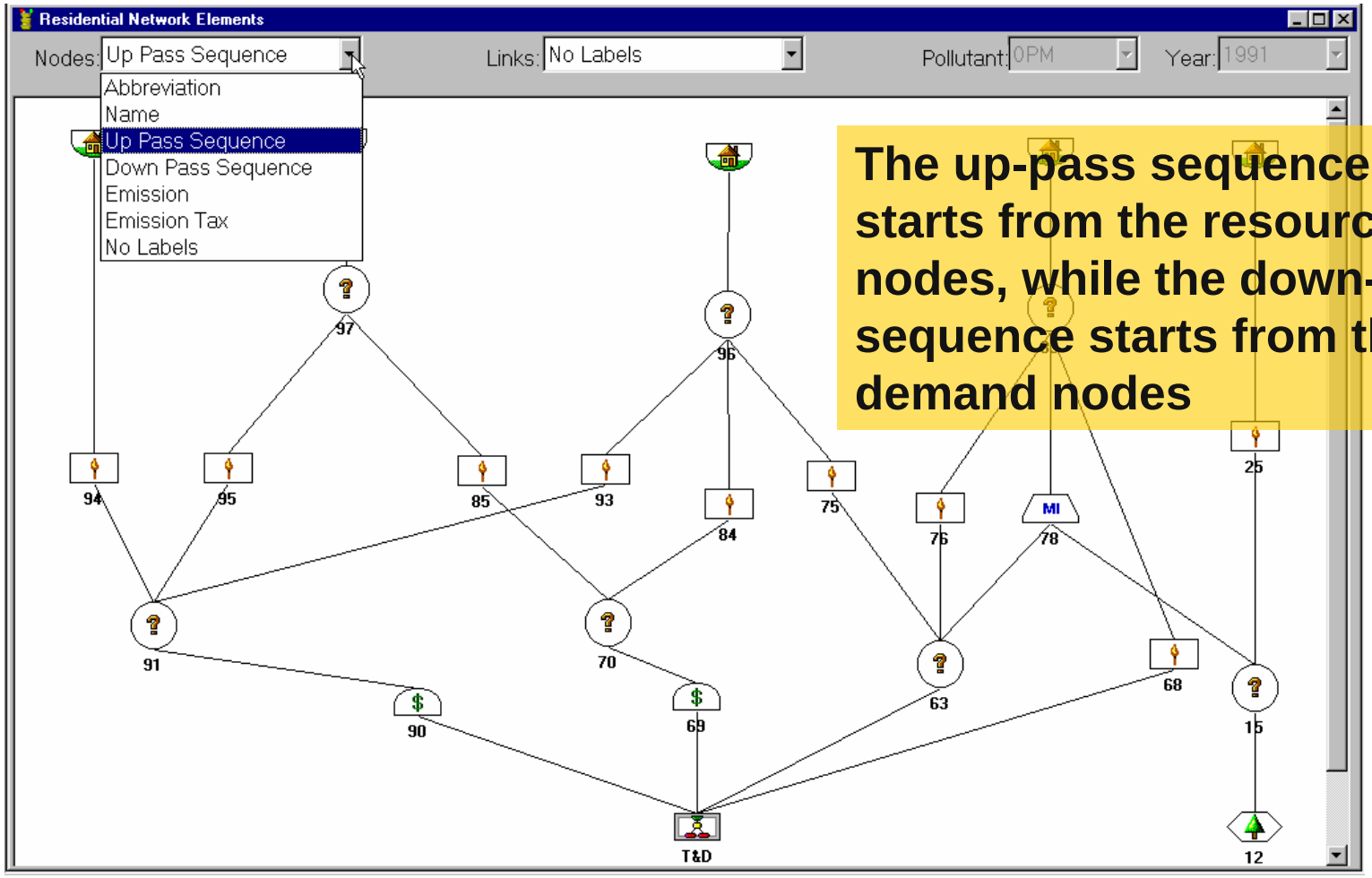
The Calculated Up/Down Node Visitation Sequence Can Be Viewed in Tabular Form



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

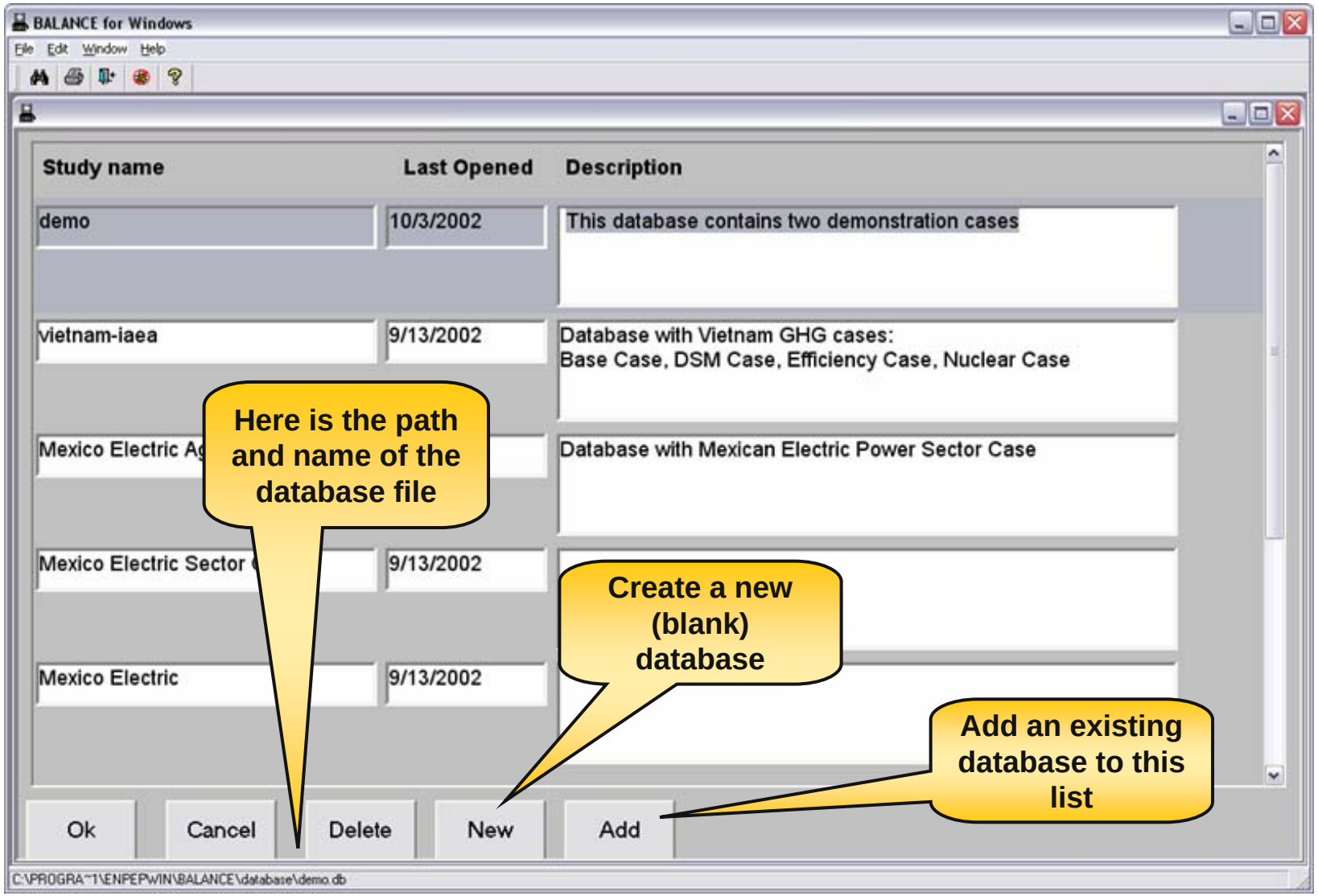
This screen also allows the user to manually adjust the node visitation sequence, if necessary.

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

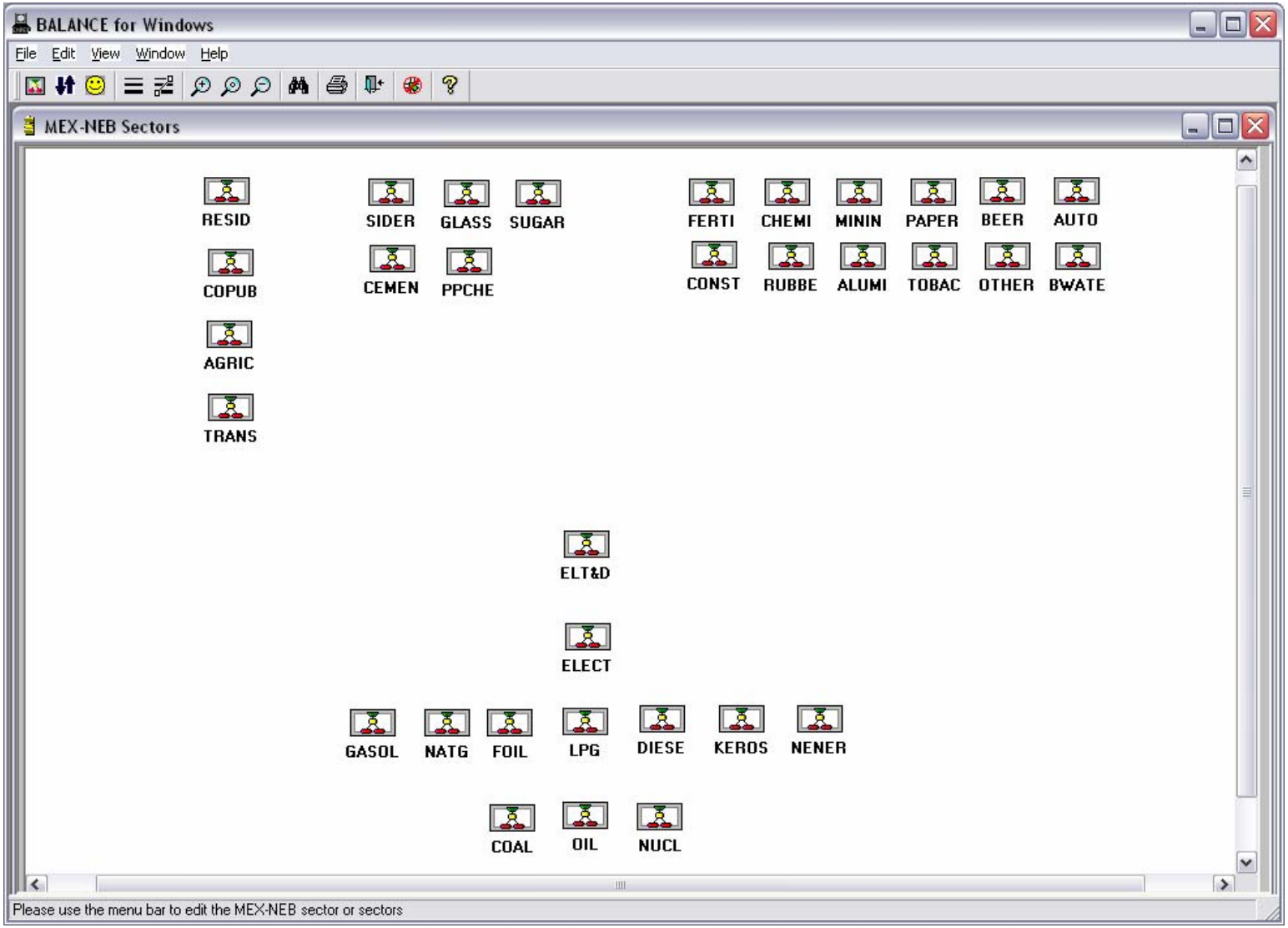


The up-pass sequence starts from the resource nodes, while the down-pass sequence starts from the demand nodes

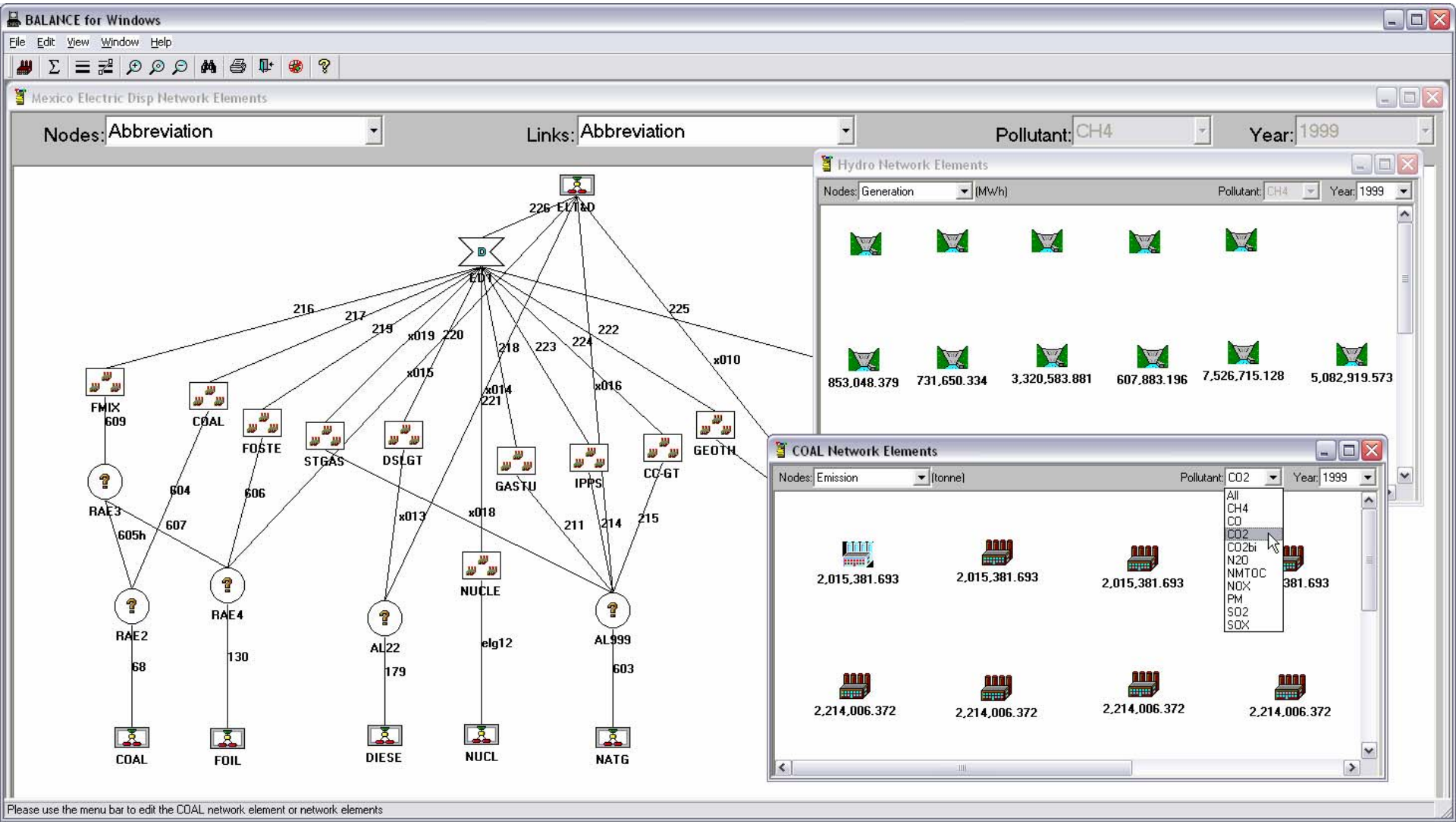
Each Case Study Can Be Stored in a Different Database



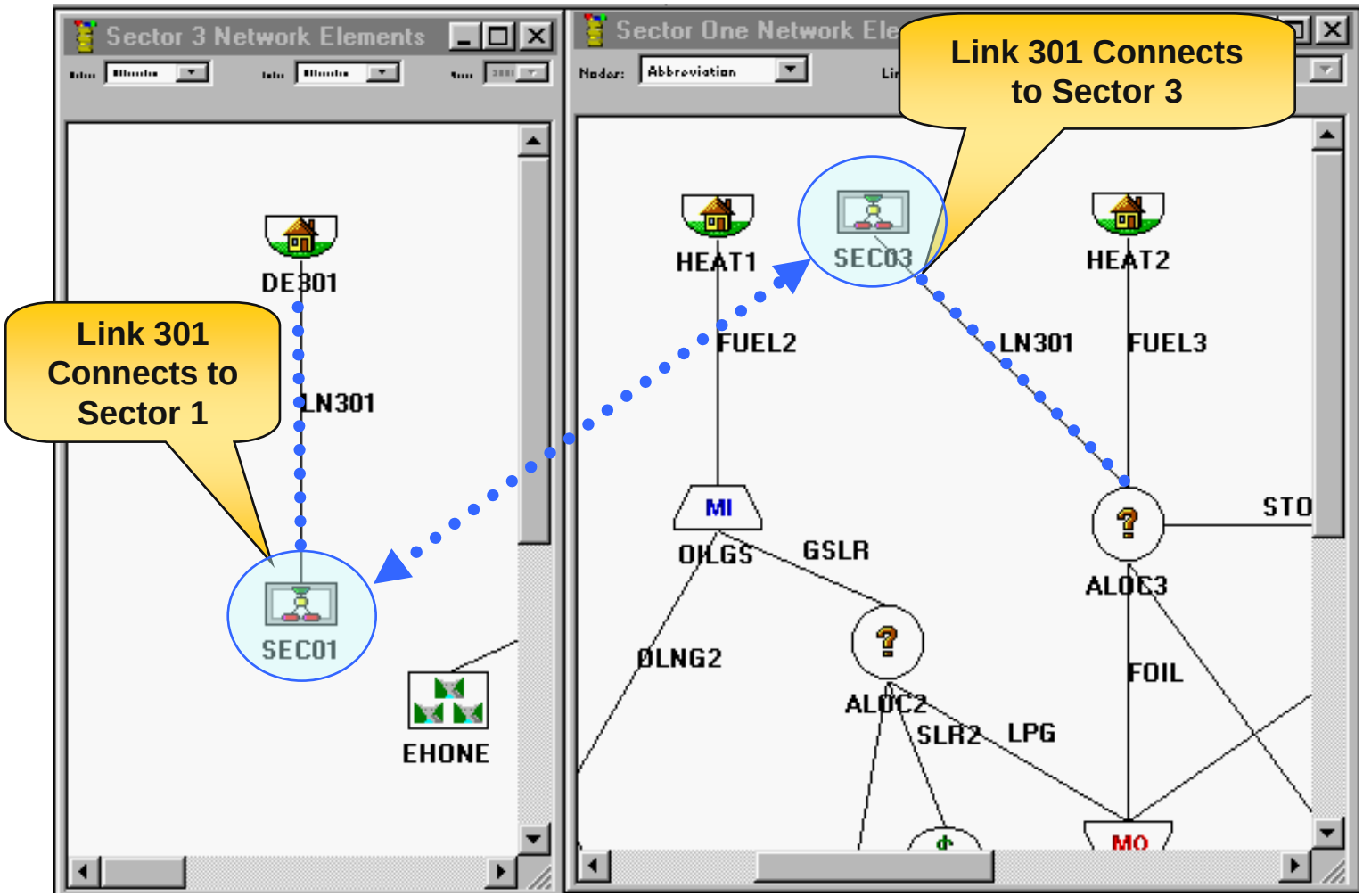
The First Step in Developing an ENPEP-BALANCE Network Is to Define the Sectors Included in Your System



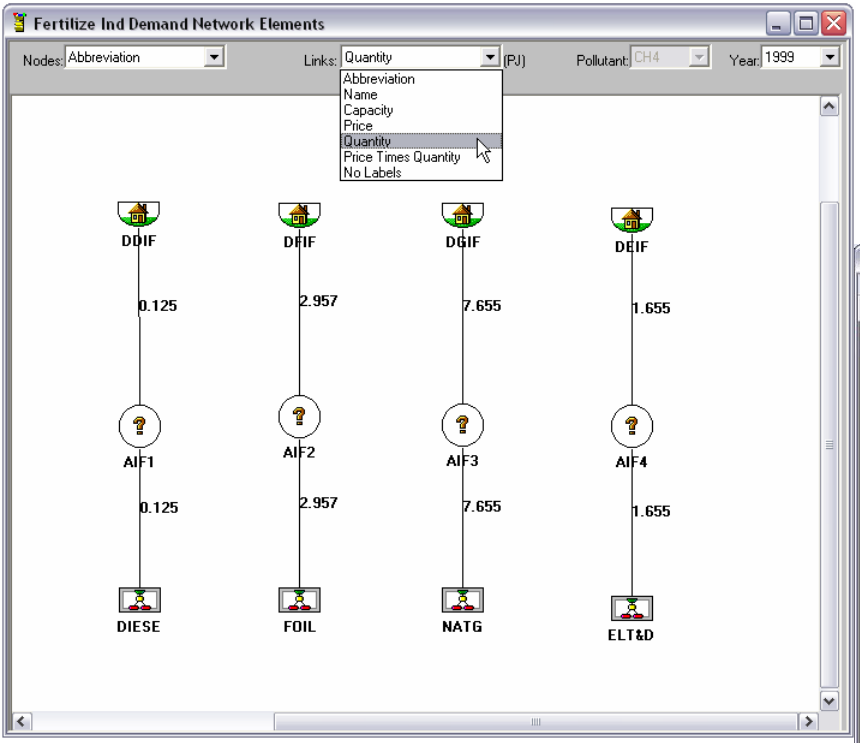
Each Sector May Be Modeled Differently Depending on Data Availability and Type of Issue Analyzed: Power Sector Can Be Modeled at the Unit Level

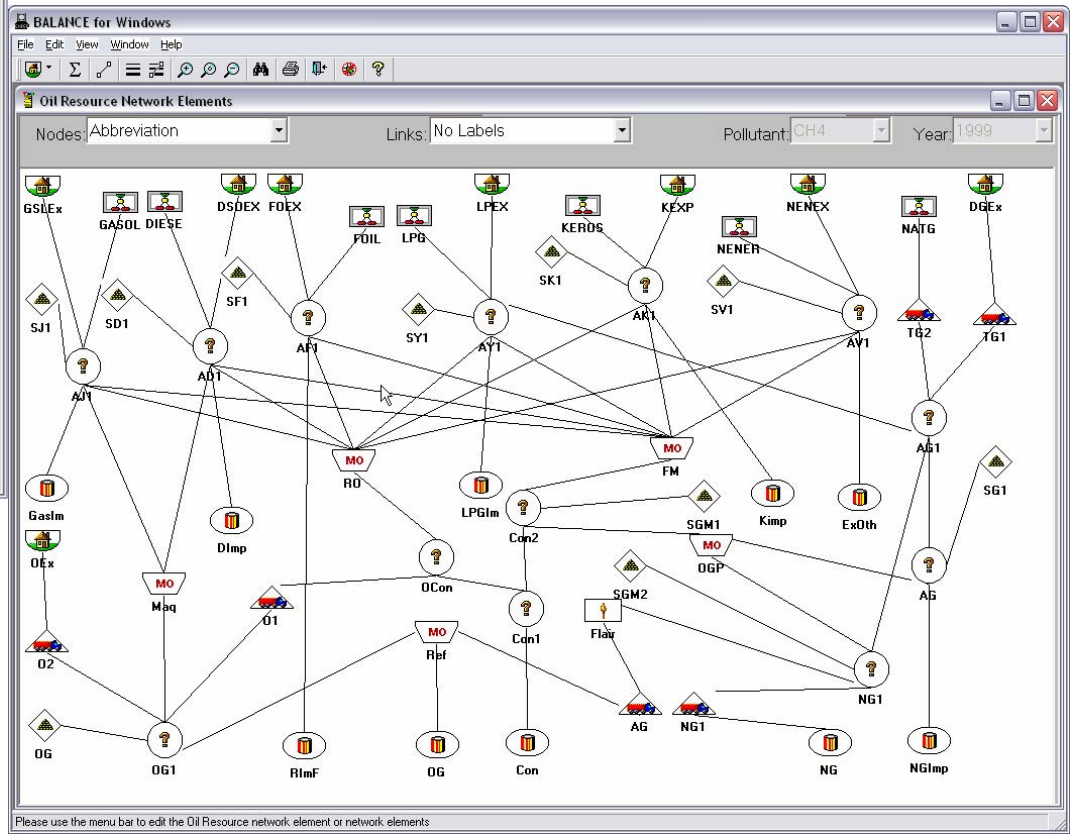


Intersectoral Links Can Connect Energy Networks of Different Sectors

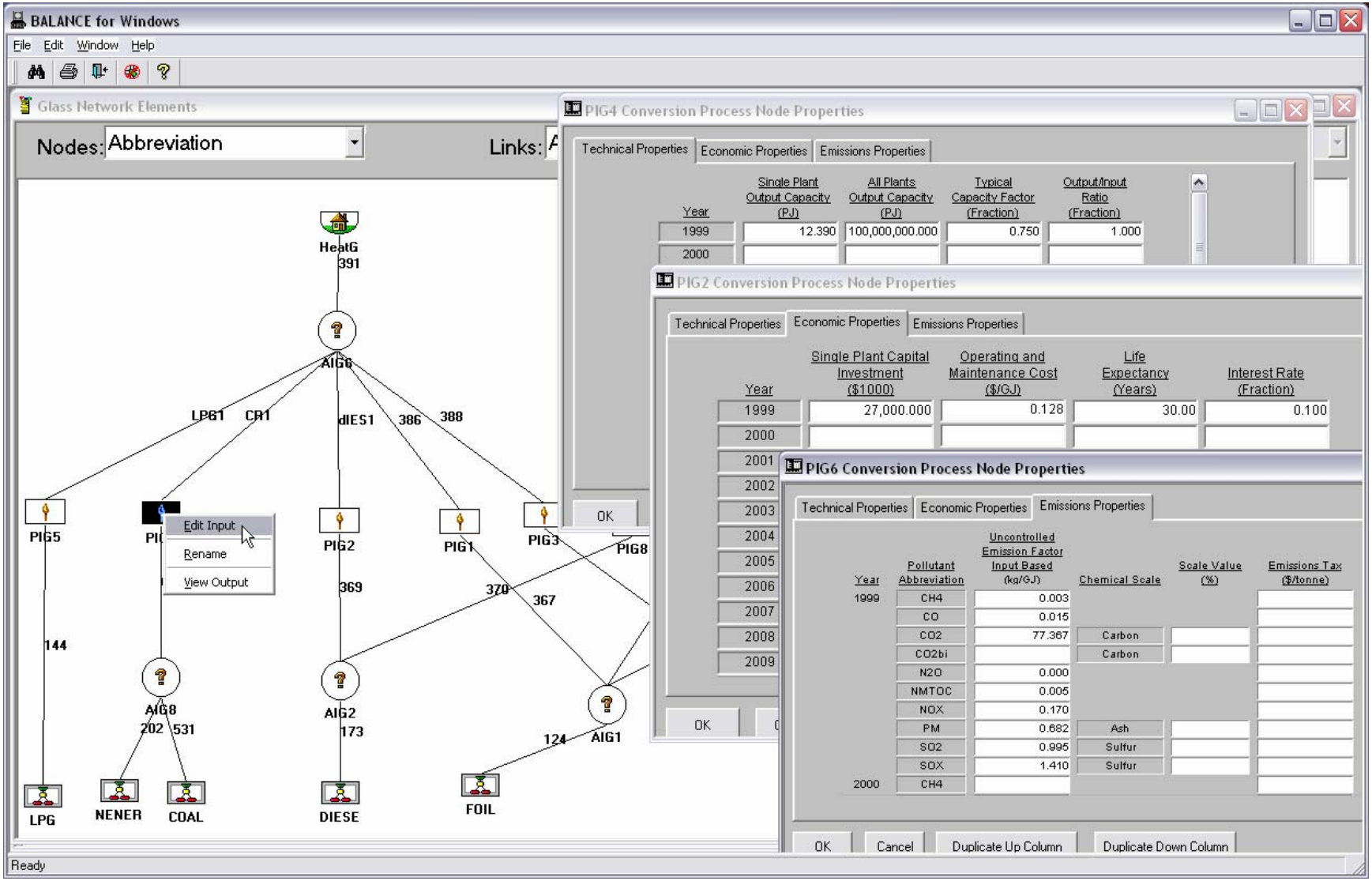


The Level of Detail May Vary from Simple to Complex: Example: Simple Fertilizer Industry and More Complex Oil & Gas Sector

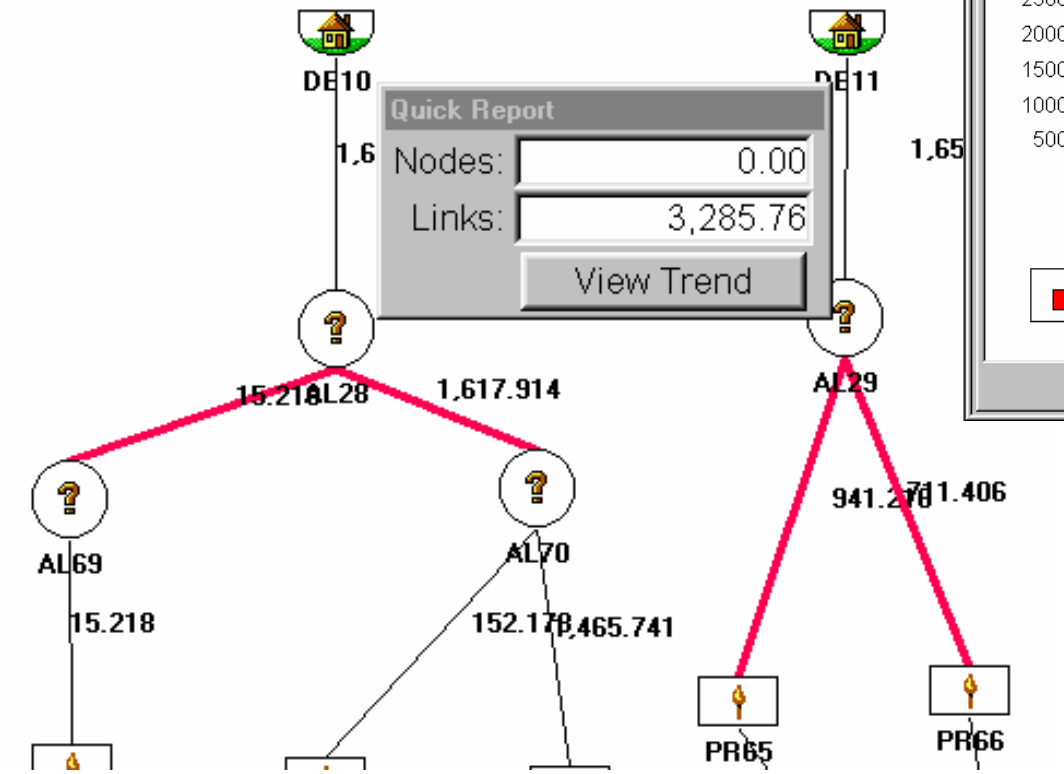


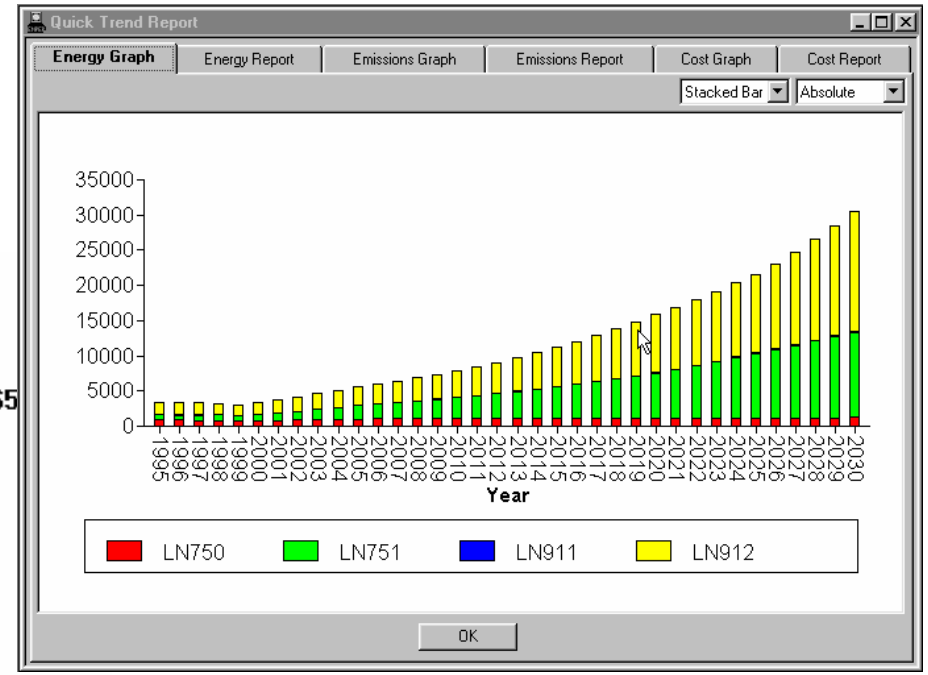


All Network Elements in ENPEP-BALANCE Can Be Accessed By Using a Standardized Simple Menu



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

Uncontrolled Emissions = Fuel Consumption x Emission Factor x Chemical Scale

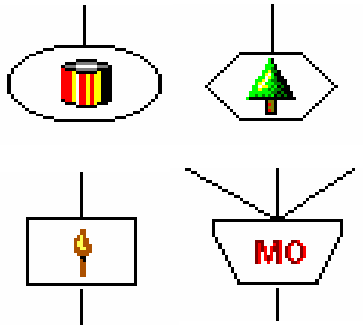
Controlled Emissions = Uncontrolled Emissions x (100 - Control Efficiency) / 100

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

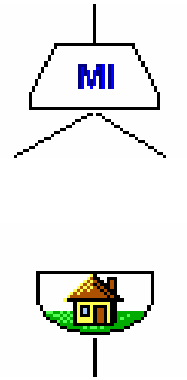
Name	Abbreviation	Chemical Scale
Methane	CH4	
Carbon Dioxide	CO2	Carbon
Nitrous Oxides	N2O	
Non Methane Total Organic Compounds	NMTOC	
Nitrogen Oxides	NOX	
Particulate Matter Total	PM	Ash
Sulfur Dioxide	SO2	Sulfur
Carbon Monoxide	CO	

OK | Cancel | Add | Delete



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

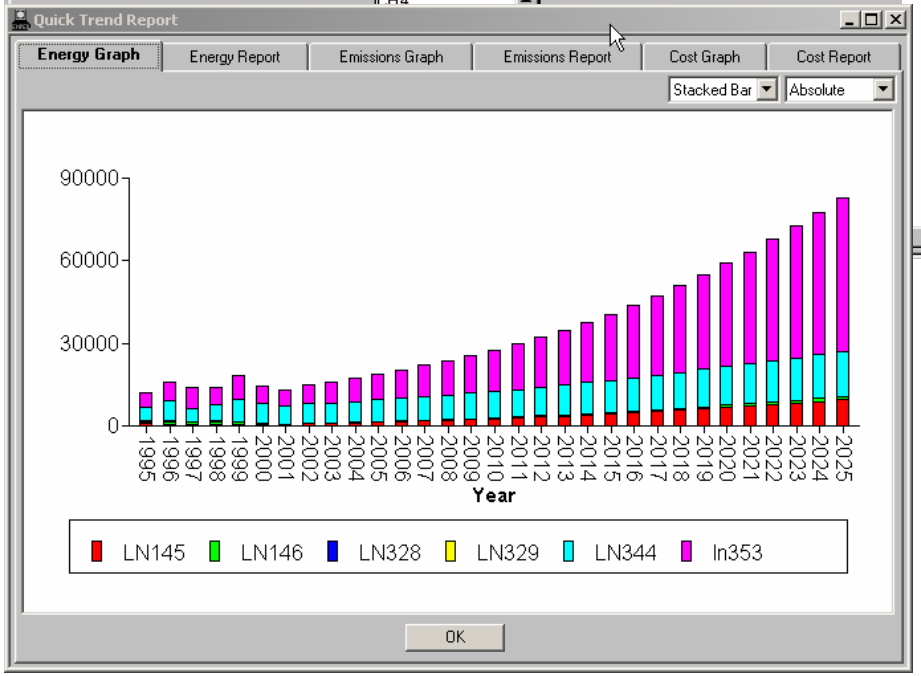


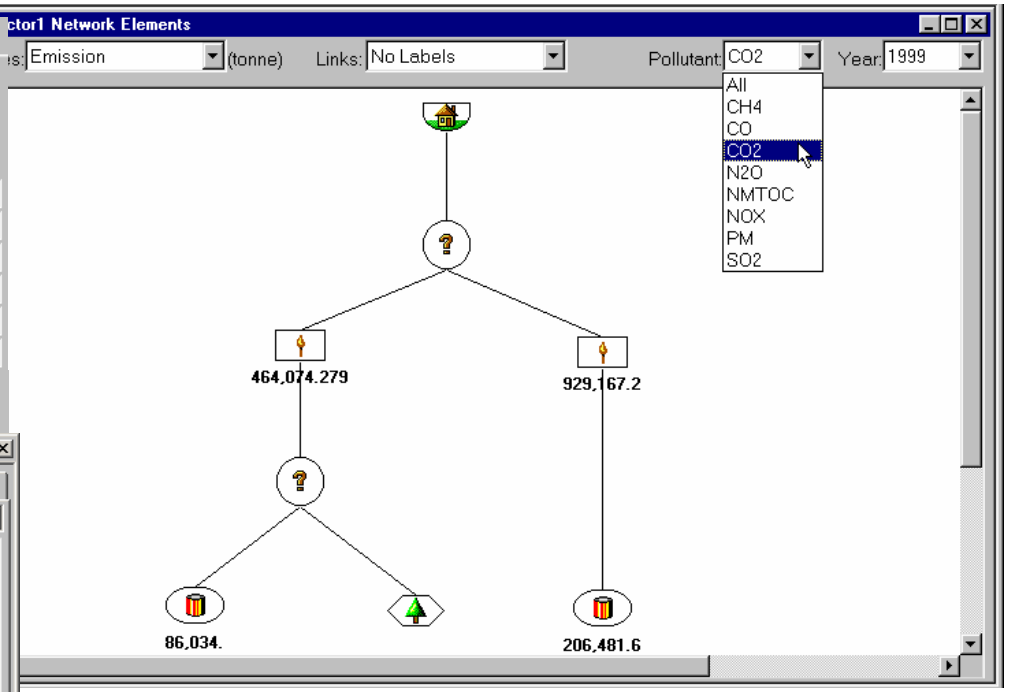
Environmental Results Can Be Viewed Directly in the Network, in Tables, Simple Graphs, or Exported to EXCEL

Energy Report | Energy Graph | Environmental Report | Environmental Graph

Year	Input Quantity (kBOE)	Pollutant Abbreviation	Emission Factor 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

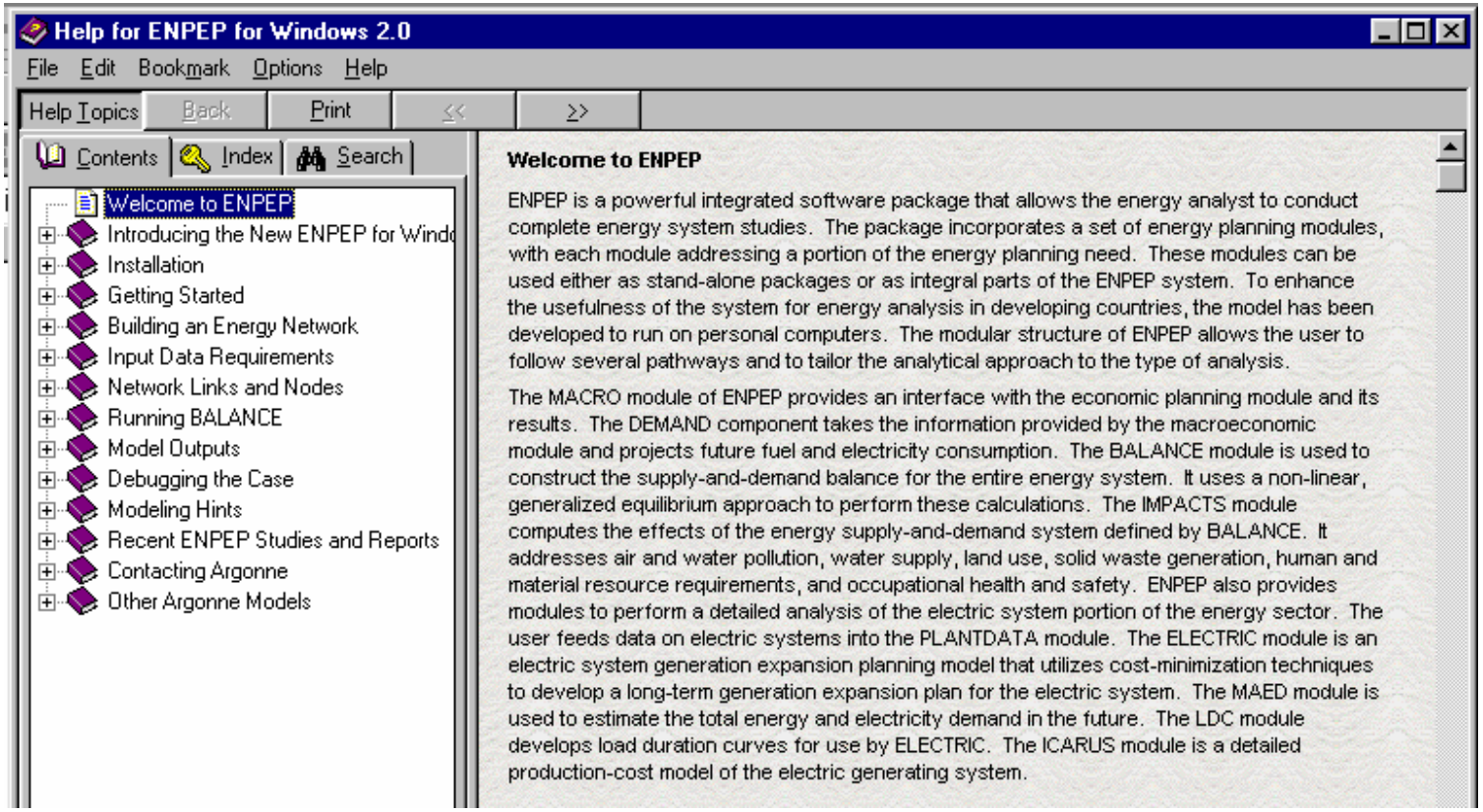
Selected Pollutant: CO2



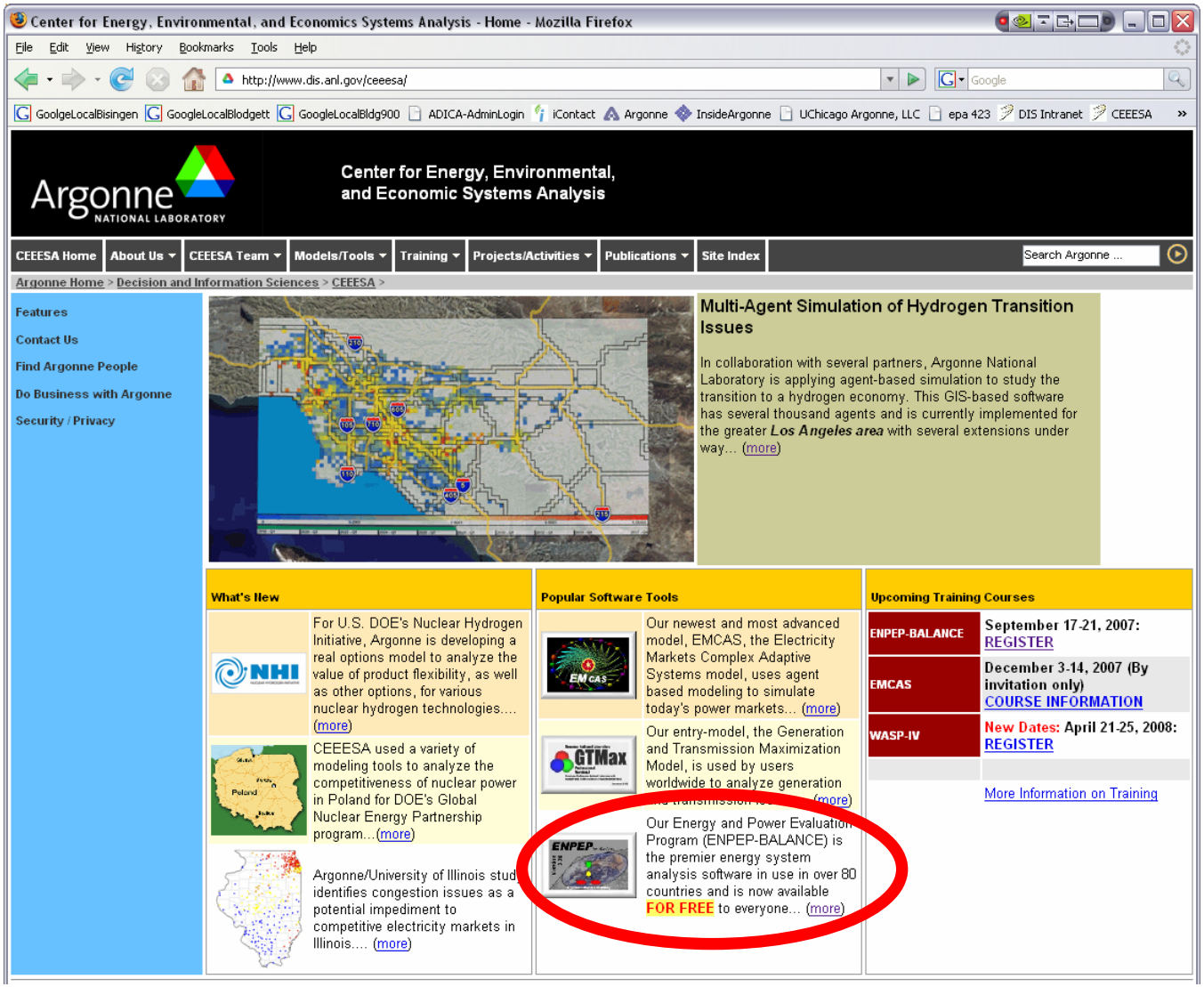


	A	B	C	D	E	F	G	H
1	DemoC Export to TXT Nodes emissions				13-Feb-01	11:40		
2								
3	Base	Nb of	Nb of	Nb of				
4	Year	Years	Nodes	Pollutants	Unit			
5								
6	1991	30	79	10	tonne			
7								
8								
9	Sector	Node	Type	Pollutant	1991	1992	1993	1994
10	AG	DE23	DE	0PM	1658.296	1741.211	1822.874	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



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