

Demo/Work Session Developing a Simple Energy Network

**Workshop on Developing National Long-Range Nuclear
Energy Strategies**

Argonne, August 8-19, 2011

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

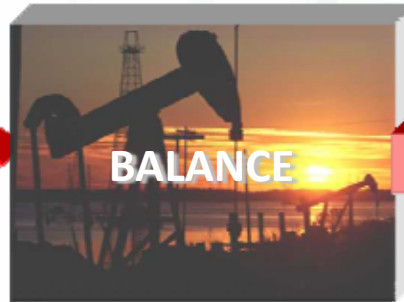
Introductory Points

- This is a simple exercise
 - Simple model approach
 - Simple case configuration
- Exercise is meant to show the influence of various parameters
 - Technical
 - Economic
 - Environmental
- Please work in teams in case we have insufficient number of computers/laptops
 - It's more fun, too
- We will walk you through the development of the initial case study
 - You will then run various scenarios (with our help)
- Discussions could focus on findings, explanations for results, limitations of the model and model setup, and the need for more complex tools

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

Price/Cost

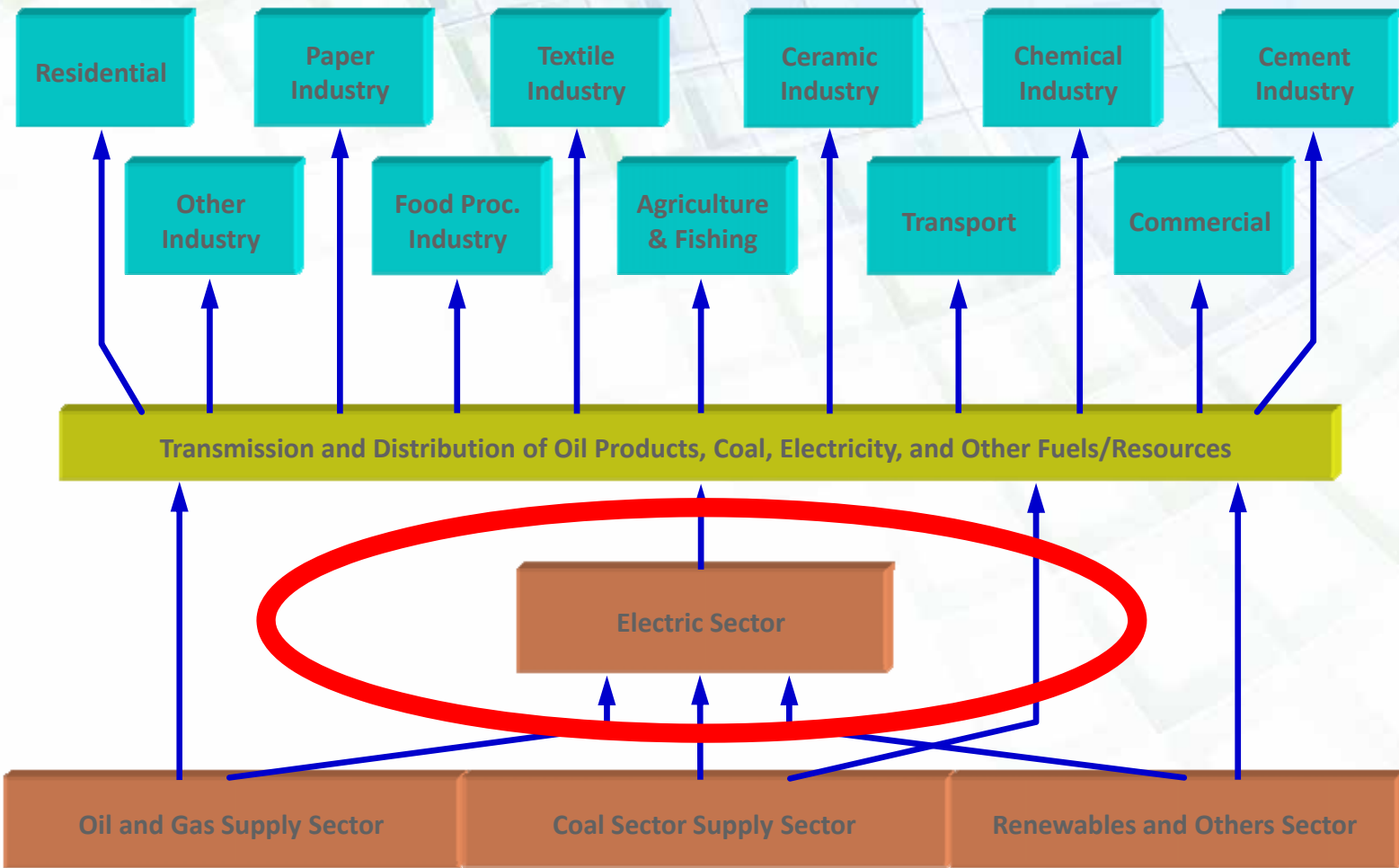
Demand

Supply

Equilibrium

Quantity

ENPEP-BALANCE Uses an Energy Network to Simulate Energy Markets (We will Focus on Electricity ONLY)



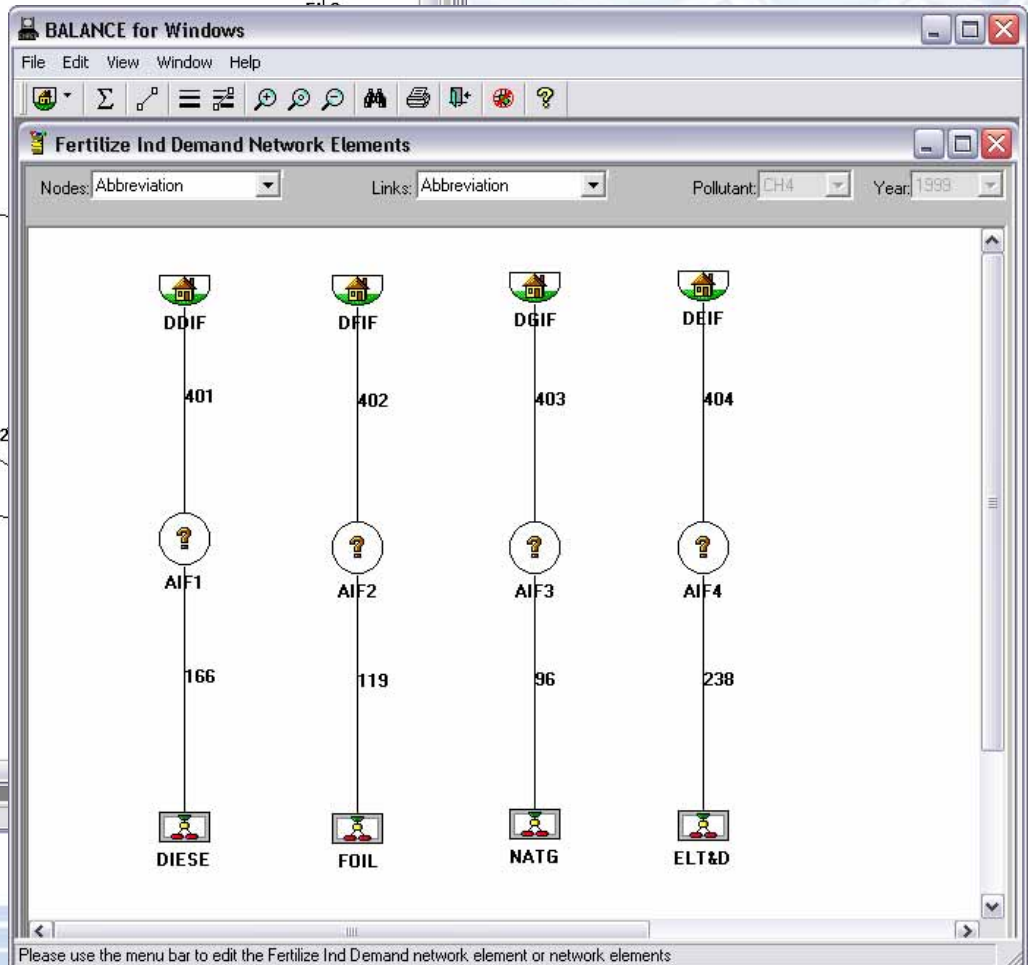
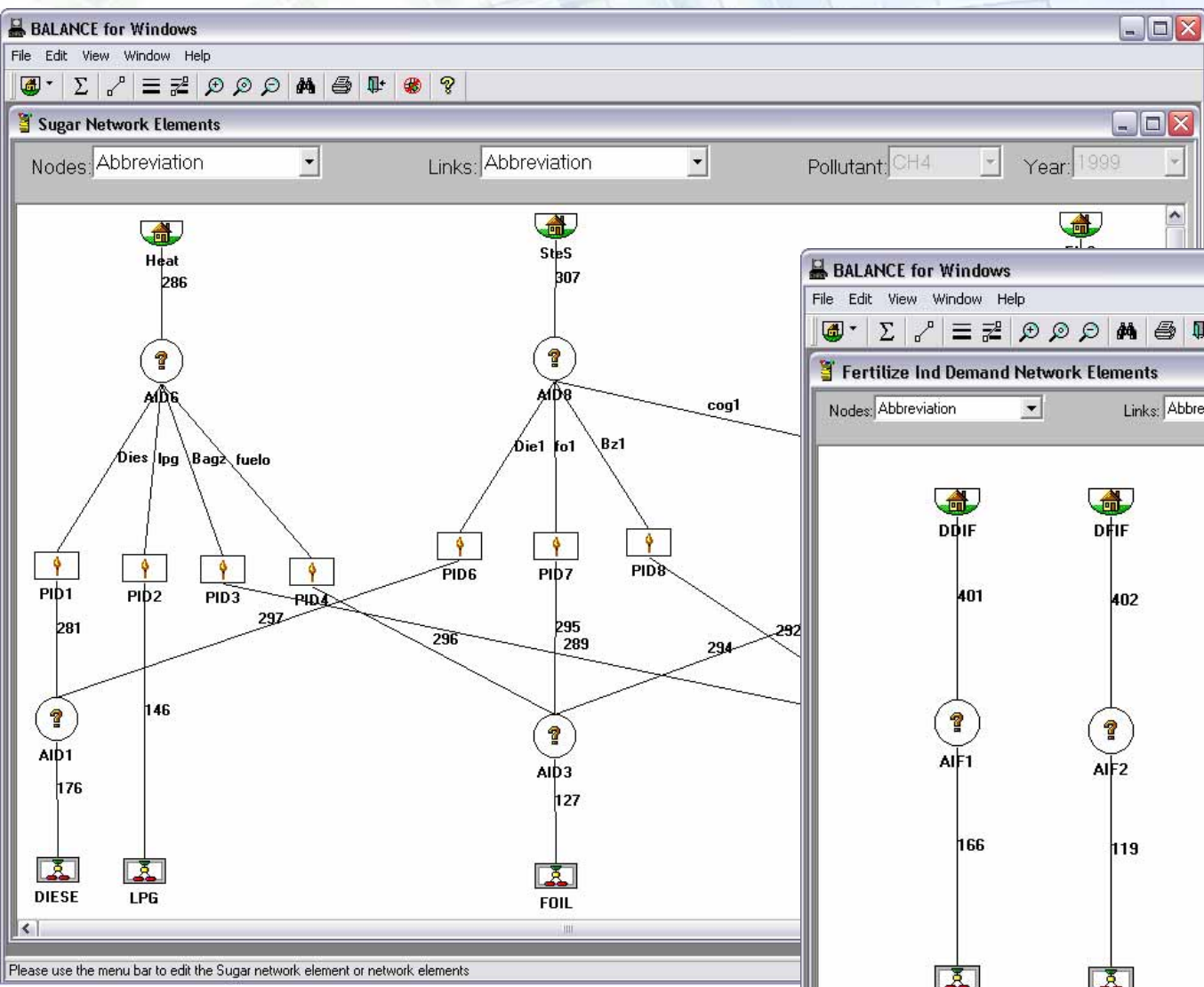
Networks are Organized into Sectors

The screenshot shows a Windows Explorer window titled "BALANCE for Windows" with a menu bar (File, Edit, View, Window, Help) and a toolbar. The main window displays a folder named "MEX-NEB Sectors" containing 28 sub-folders, each represented by a network icon and a text label. The folders are arranged in a grid-like fashion:

- Row 1: RESID, SIDER, GLASS, SUGAR, FERTI, CHEMI, MINER, PAPER, BEER, AUTO
- Row 2: COPUB, CEMEN, PPCHE, CONST, RUBBE, ALUMI, TOBAC, OTHER, BWATE
- Row 3: AGRIC
- Row 4: TRANS
- Row 5: ELT&D
- Row 6: ELECT
- Row 7: GASOL, NATG, FOIL, LPG, DIESE, KEROS, NENER
- Row 8: COAL, OIL, NUCL

At the bottom left of the window, there is a "Zoom In" button.

Network Sectors Consist of Nodes and Links

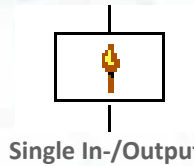


The Following Node Types are Available to Model Different Energy Activities

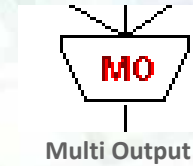
- Demand



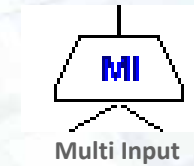
- Conversion Processes



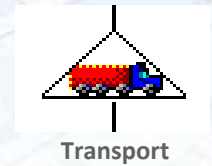
Single In-/Output



Multi Output



Multi Input

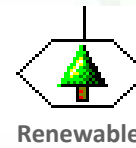


Transport

- Resource Processes



Depletable

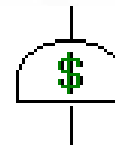


Renewable

- Economic Processes

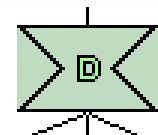


Decision/Allocation



Pricing

- Electricity Dispatch and Thermal and Hydro Units



Central Dispatch

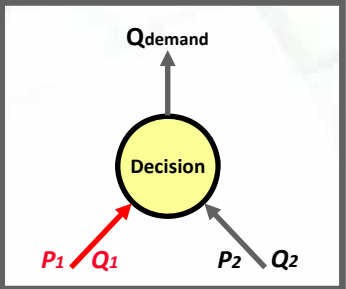


Thermal Unit



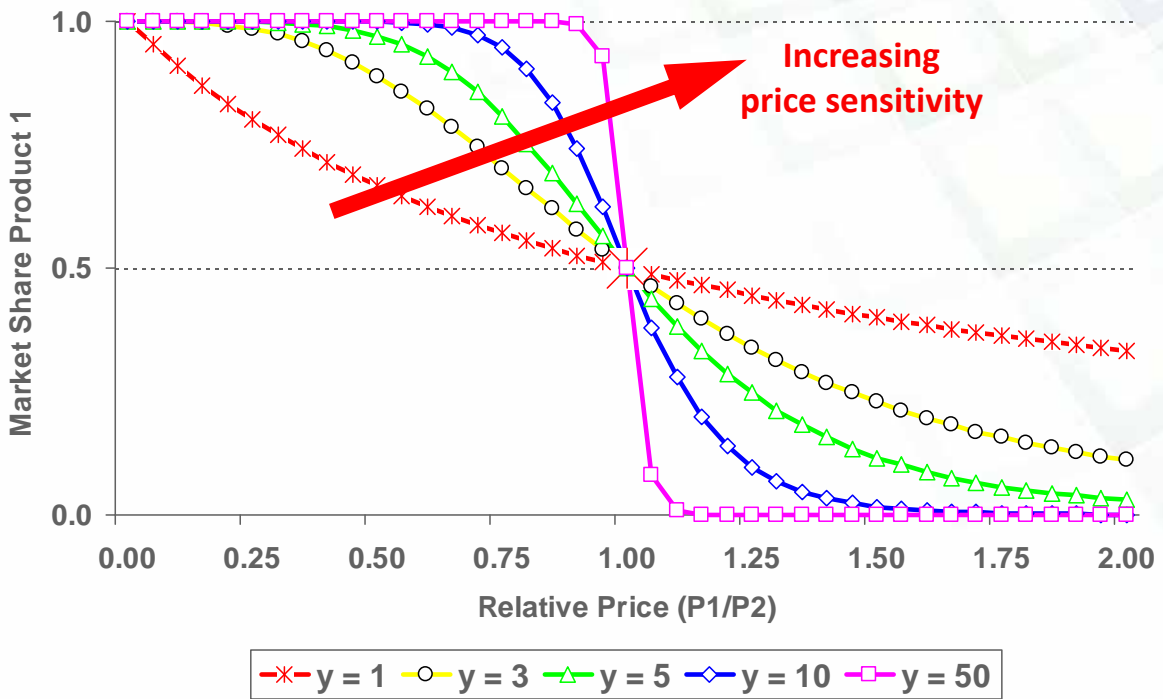
Hydro Unit

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



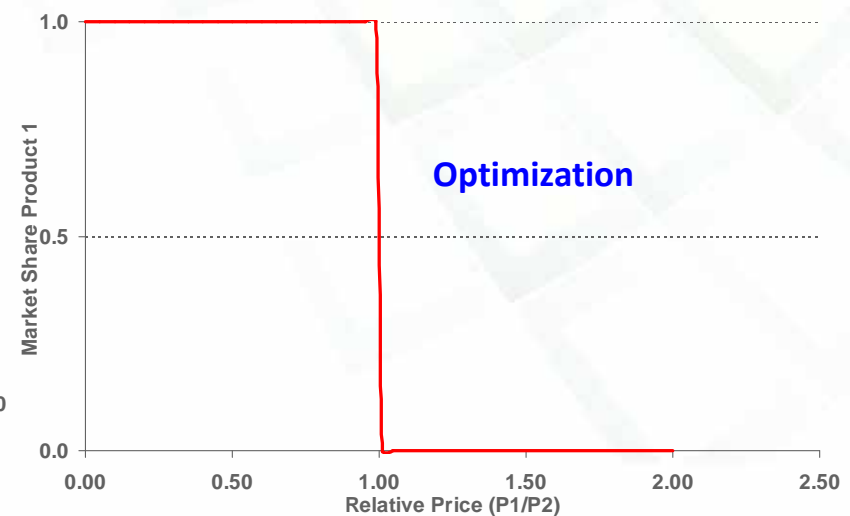
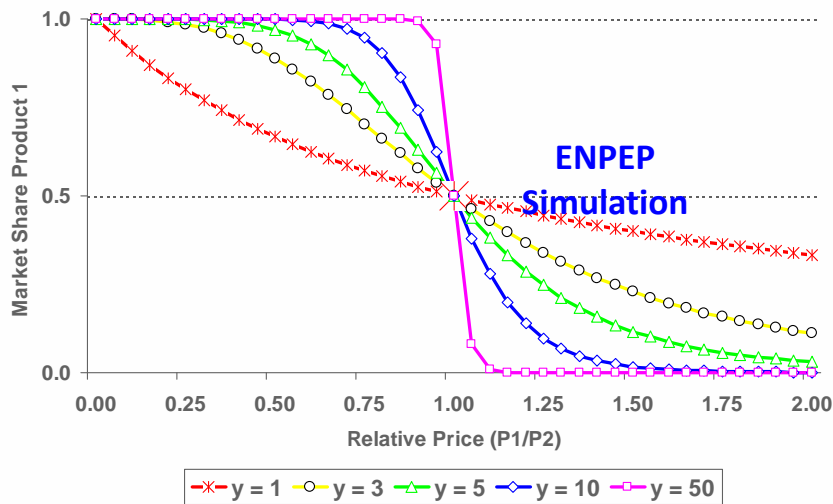
$$MS_1 = \frac{Q_1}{Q_1 + Q_2} = \frac{\left[\frac{1}{P_1 \times PM_1} \right]^\gamma}{\left[\frac{1}{P_1 \times PM_1} \right]^\gamma + \left[\frac{1}{P_2 \times PM_2} \right]^\gamma}$$

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

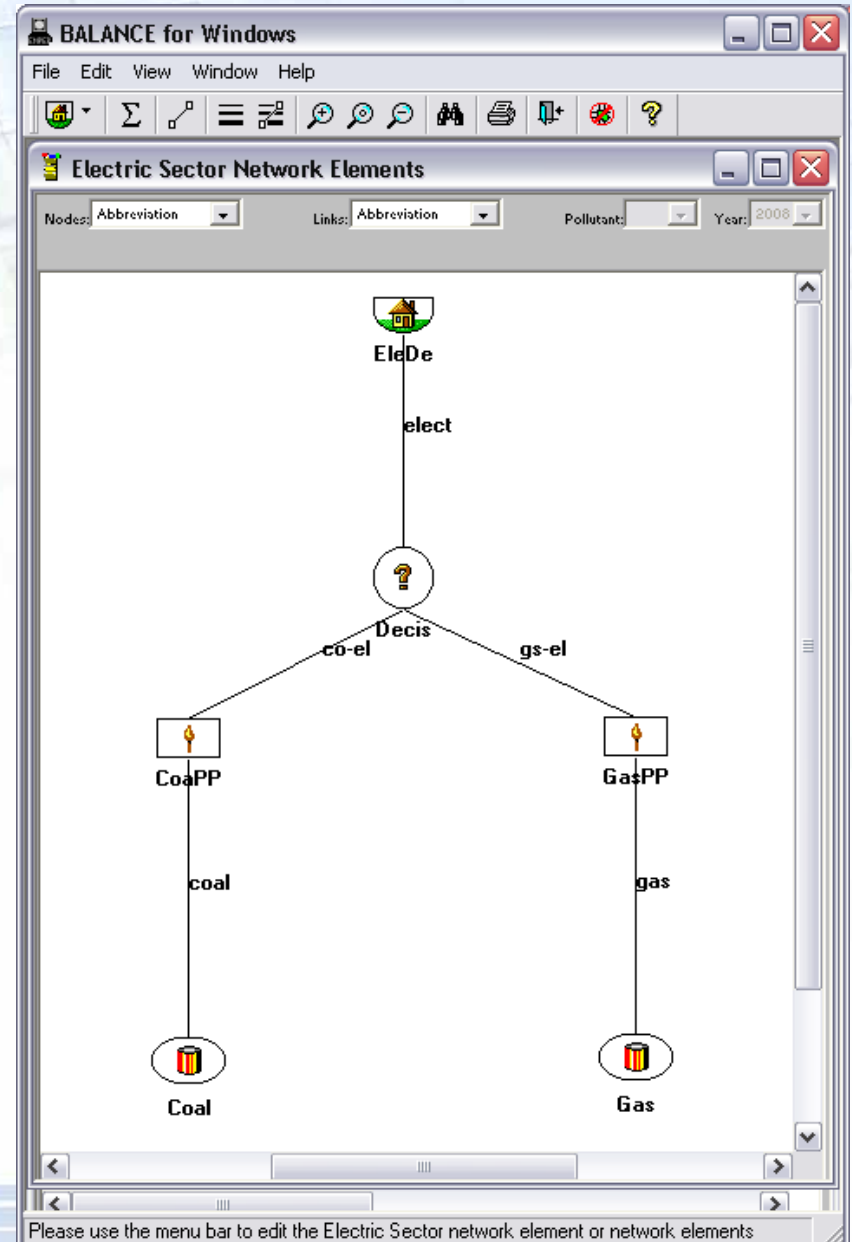
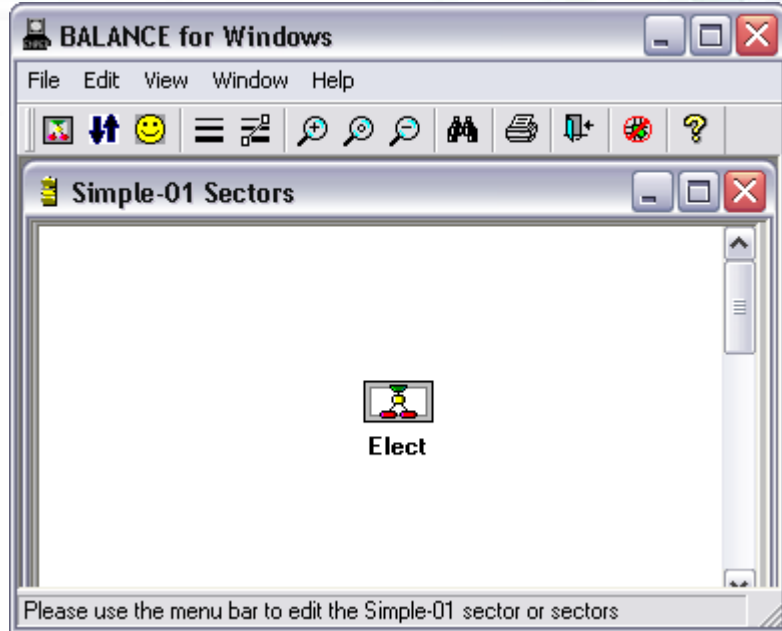


The ENPEP-BALANCE Nonlinear Equilibrium Algorithm is Based on Decentralized Decision Making

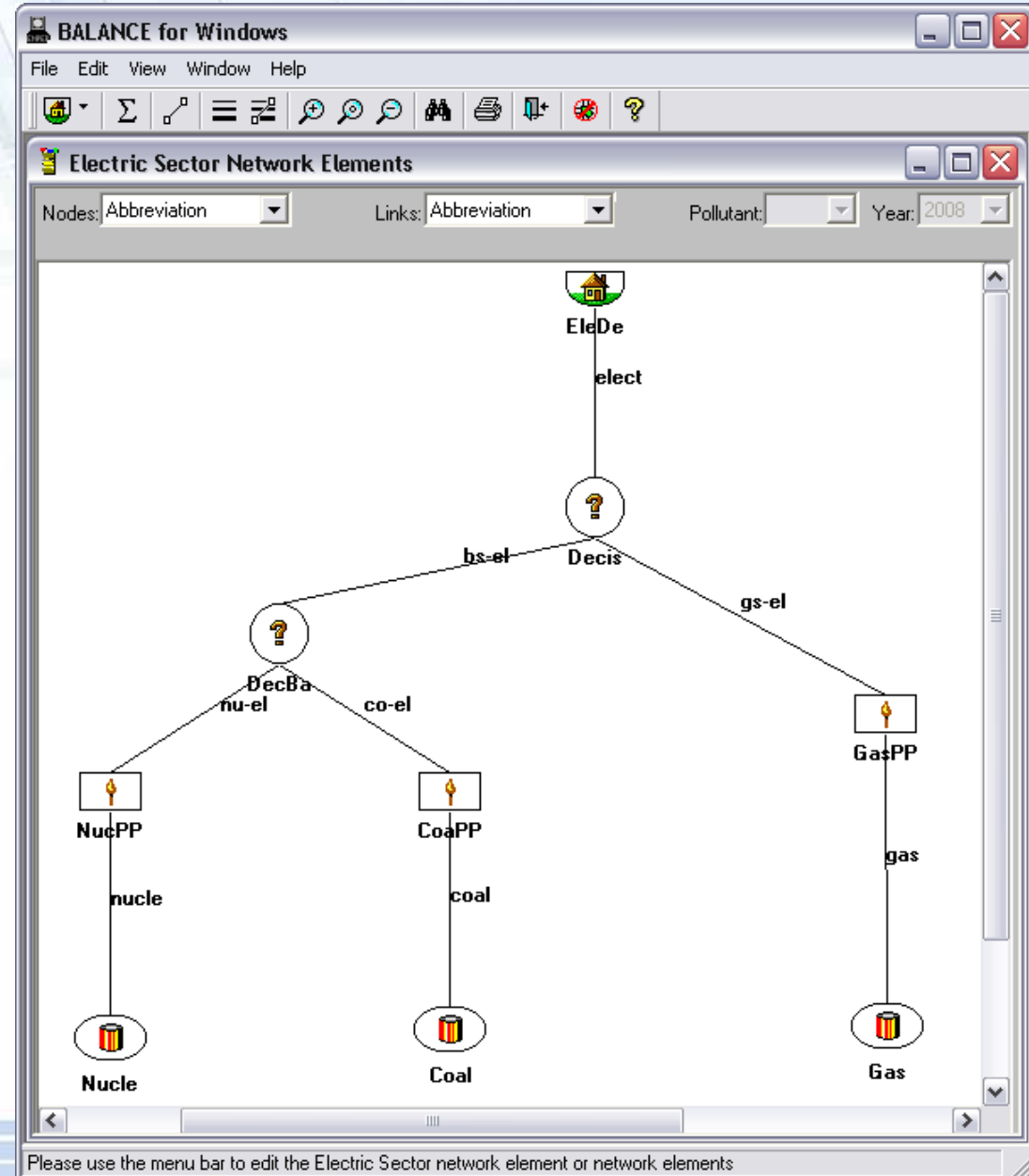
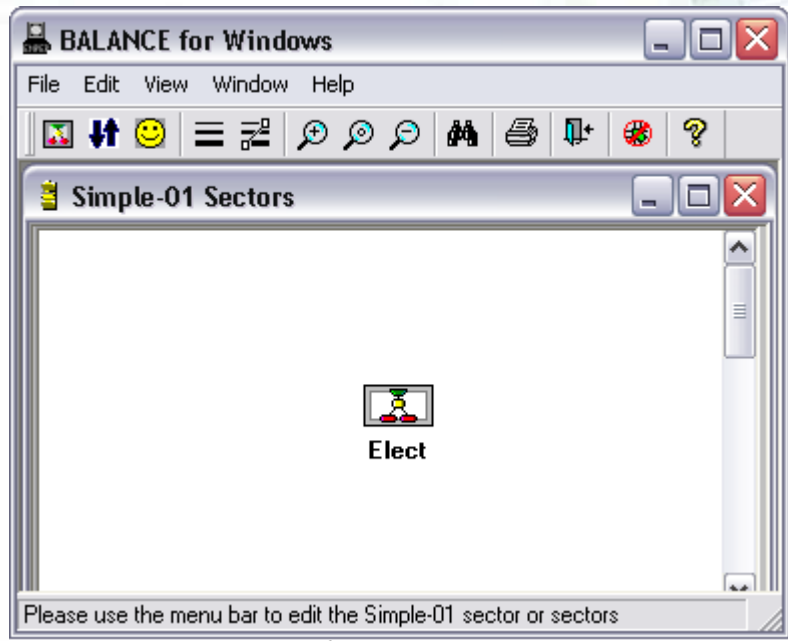
- Market share calculation assumes “ideal market” subject to government policies, fuel availability, and market constraints
- A lag factor accounts for delays in capital stock turnover
- The result is a nonlinear, market-based equilibrium solution within policy constraints, not a simple, linear optimization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



Network for our Simple Case Study – We will Start with One Sector (Electric) and 2 Power Plants

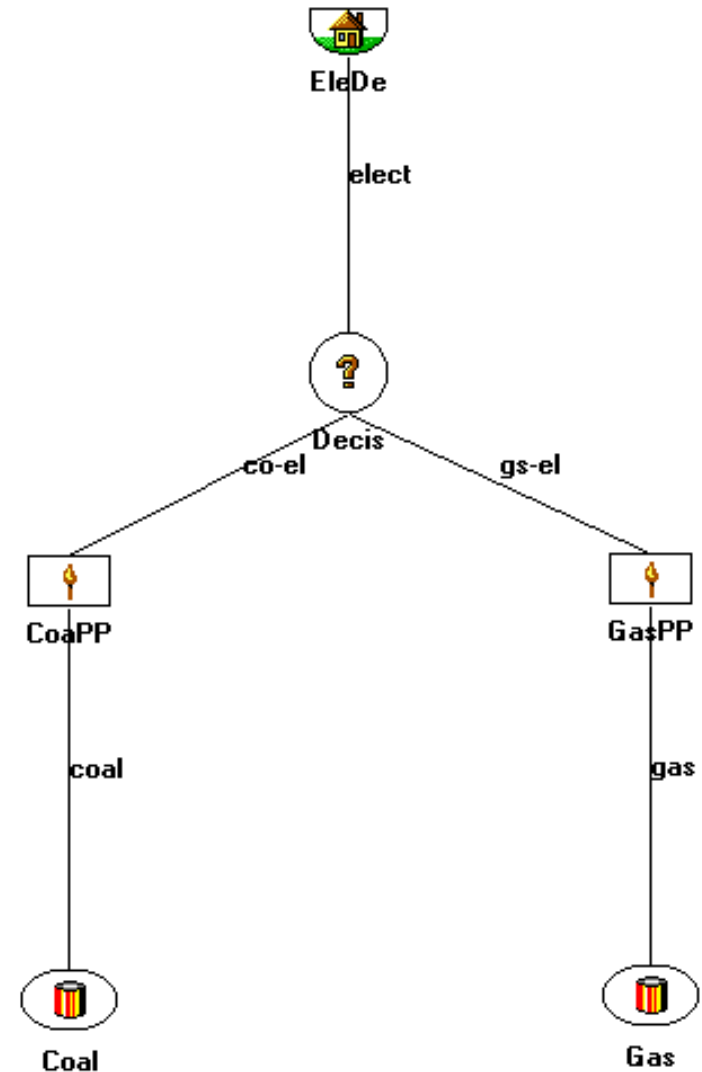


Later, we will Add one more Technology to the Mix and Change the Configuration Slightly



Configuration of the Simple Case Study

- Two fuel sources
 - Coal
 - Natural gas
- Two power plants (conversion processes)
 - Coal power plant
 - Natural gas power plant
- One decision point/node
 - Choice between electricity from coal or gas
- One demand node: Electricity
- Study period: 30 years, 2009-2038



Steps in Developing the Simple Case Study

- Prepare the power system structure (see Steps 1 – 10 on following slides)
 - Draw the system using nodes and links
 - Label each system element
 - Each link and node has a name and abbreviation
- Execution Step 1: Validate network structure
 - Click on “**up-down**”
 - Necessary when arrows are **RED**
- Enter the input data
- Execution Step 2: Run the simulation
 - Click on “**Run BALANCE**”
 - Necessary when face is **RED (sad)**
- Review and interpret the results



STEP 1: Create a New DATABASE

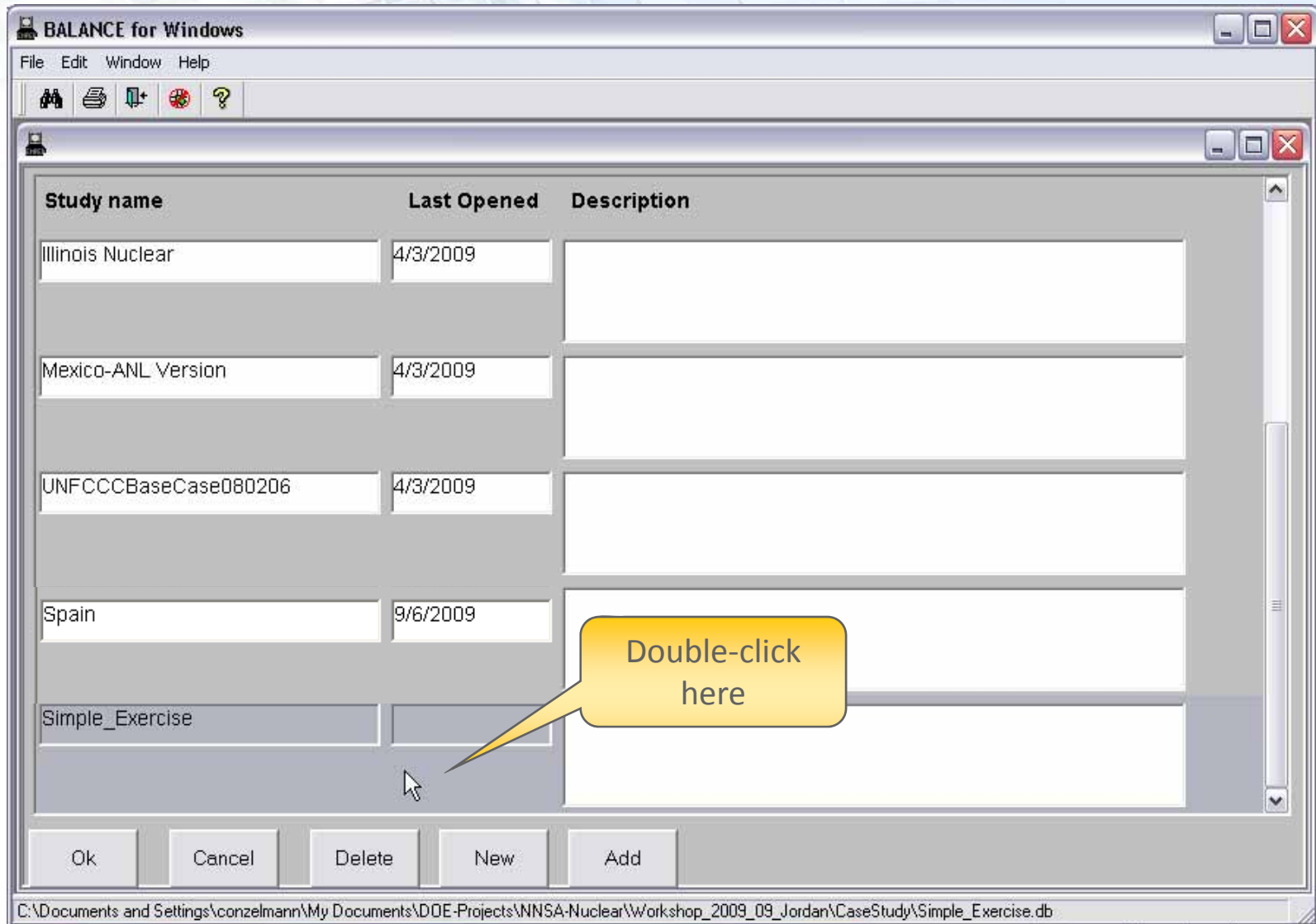
The screenshot shows the 'BALANCE for Windows' application window. A 'Type New File Name' dialog box is open, displaying a file explorer view of the 'CaseStudy' folder. The 'File name' field contains 'Simple_Exercise' and the 'Save as type' is set to 'BALANCE Studies (*.db)'. The 'Save' button is highlighted. Below the dialog box, a table of data is visible, with the 'New' button at the bottom highlighted. Four yellow callout boxes provide instructions:

- (1) Click **NEW**
- (2) Use the pulldown to choose the folder where you want to save the database
- (3) Enter name of new database, e.g., **Simple_Exercise**
- (4) Click **SAVE**

Location	Date
Spain	9/6/2009
Illinois Nuclear	4/3/2009
Mexico-ANL Version	4/3/2009



STEP 2: Open the New Database; Highlight the Name and Double-click



STEP 3: Create a New CASE

The screenshot shows the 'BALANCE for Windows' application with the 'Simple_Exercise' dialog box open. The dialog box contains a table with columns 'Name', 'Abbreviation', and 'Description'. Below the table are input fields for 'Simple-01', 'Sim01', and 'Simple Case 1: Base Case'. At the bottom of the dialog are buttons for 'OK', 'Cancel', 'Add', and 'Delete', along with 'Start Year: 2009' and 'End Year: 2038'.

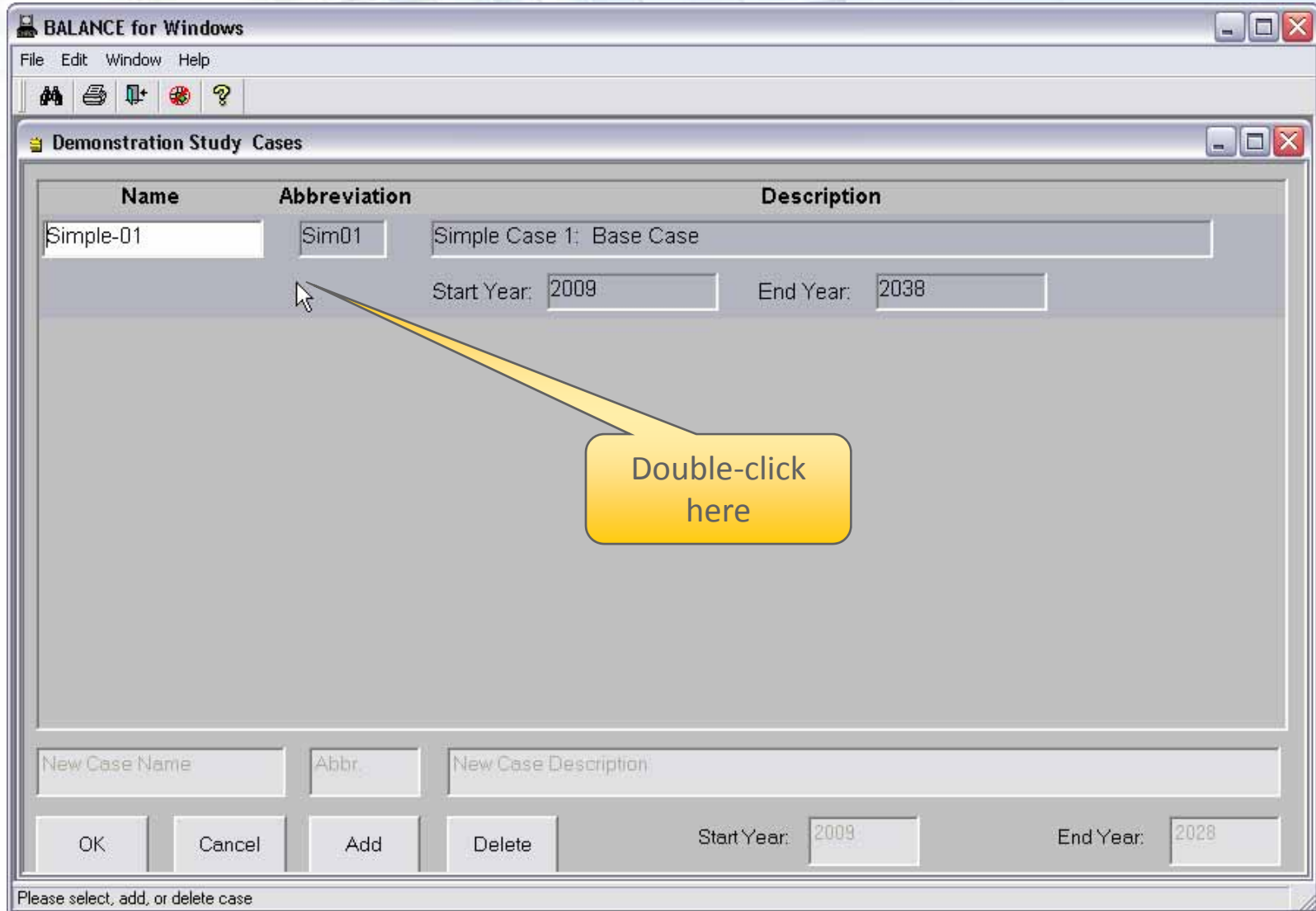
Callout (1) Click **ADD** points to the 'Add' button in the bottom-left corner of the dialog box.

Callout (2) Enter Name, Abbreviation, Description, Start Year, and End Year points to the input fields for 'Simple-01', 'Sim01', 'Simple Case 1: Base Case', '2009', and '2038'.

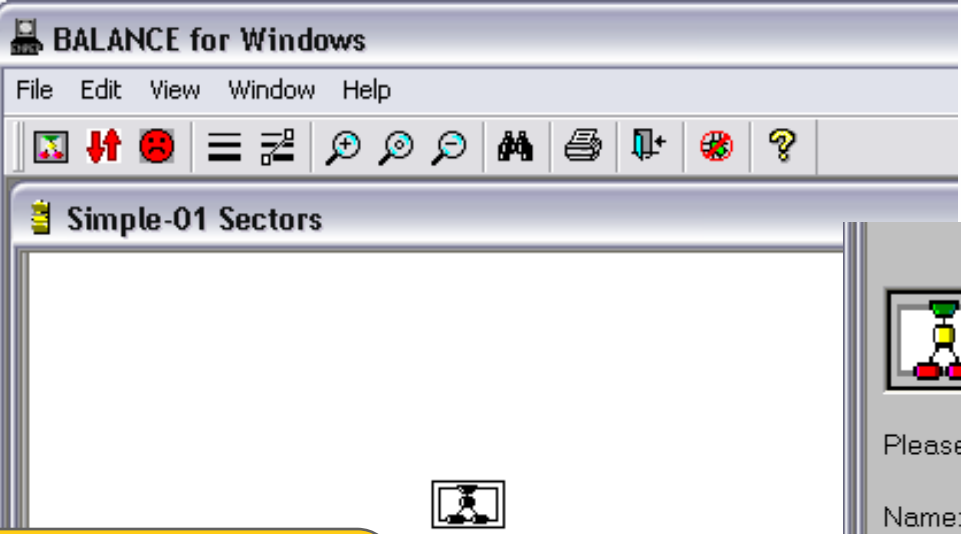
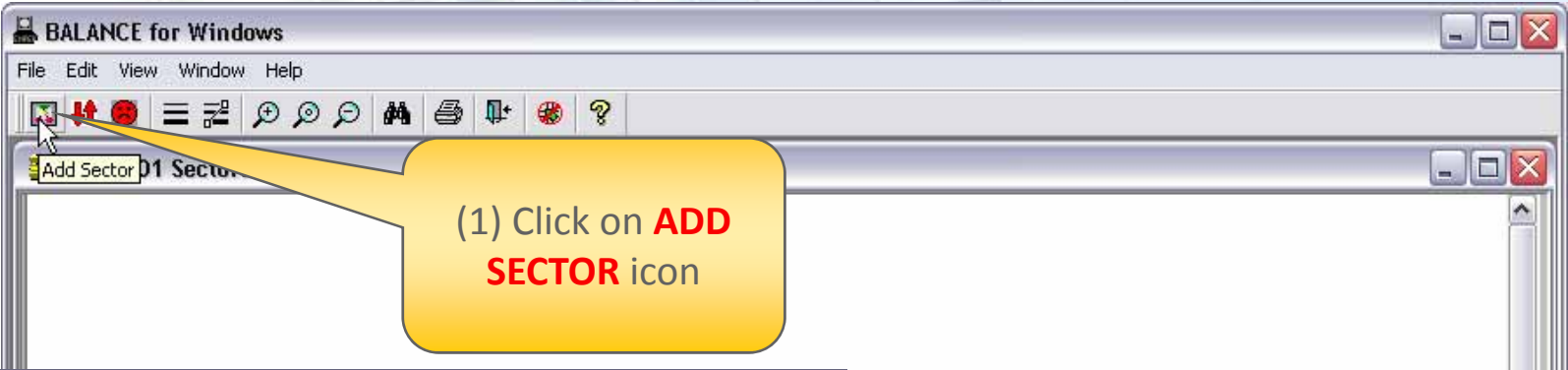
Callout (3) Click **OK** points to the 'OK' button in the bottom-left corner of the dialog box.



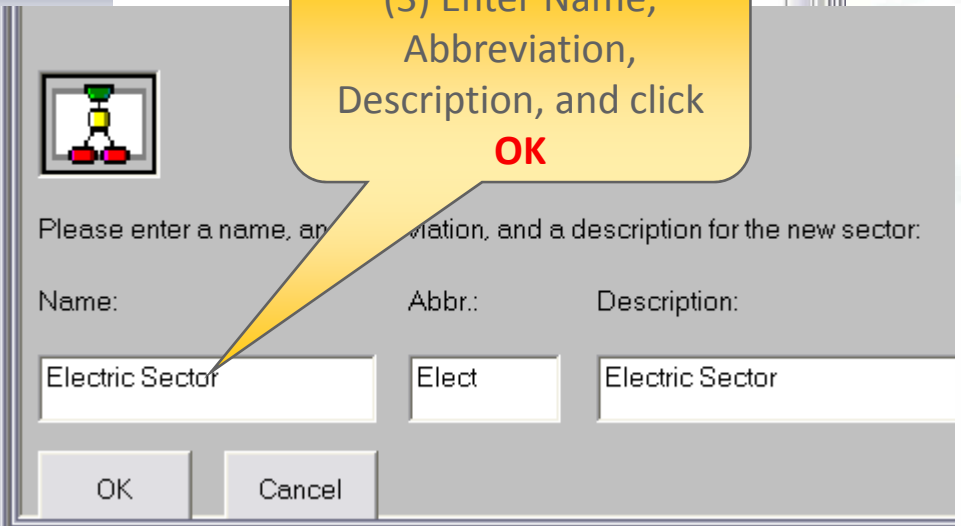
Step 4: Open the New Case ; Highlight the Name and Double-click



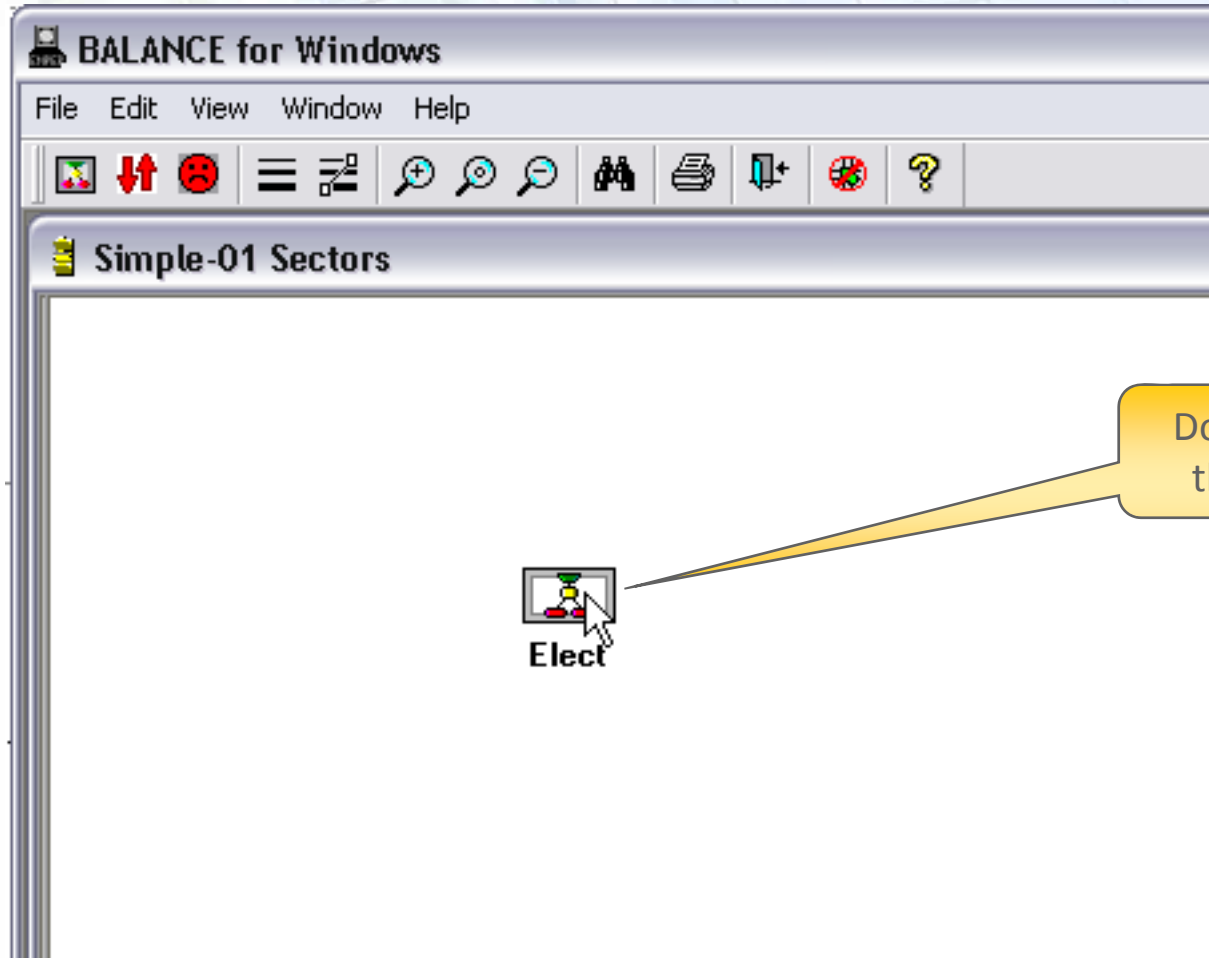
Step 5: Create New Sector and Name the Sector



(2) Move the mouse to where you want to place the sector and click



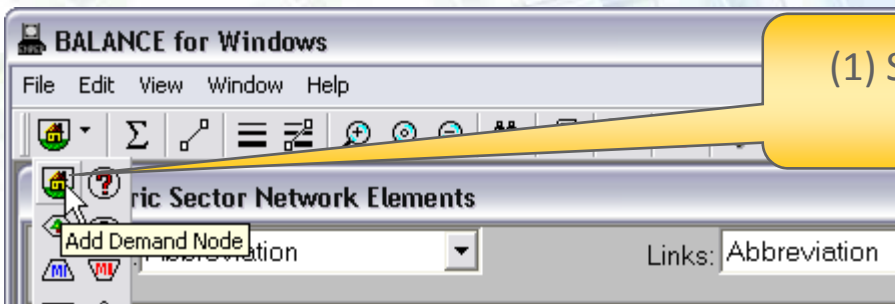
Step 6: Enter the Sector by Double-clicking



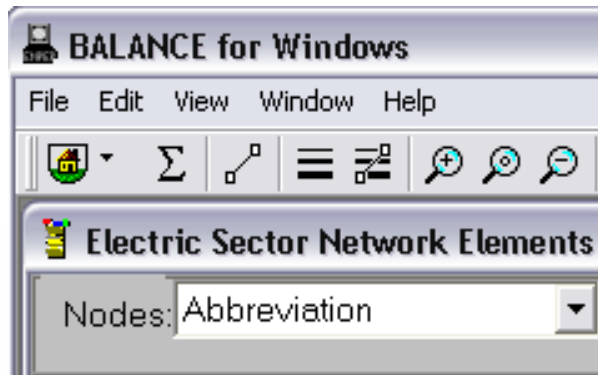
Double-click
the sector



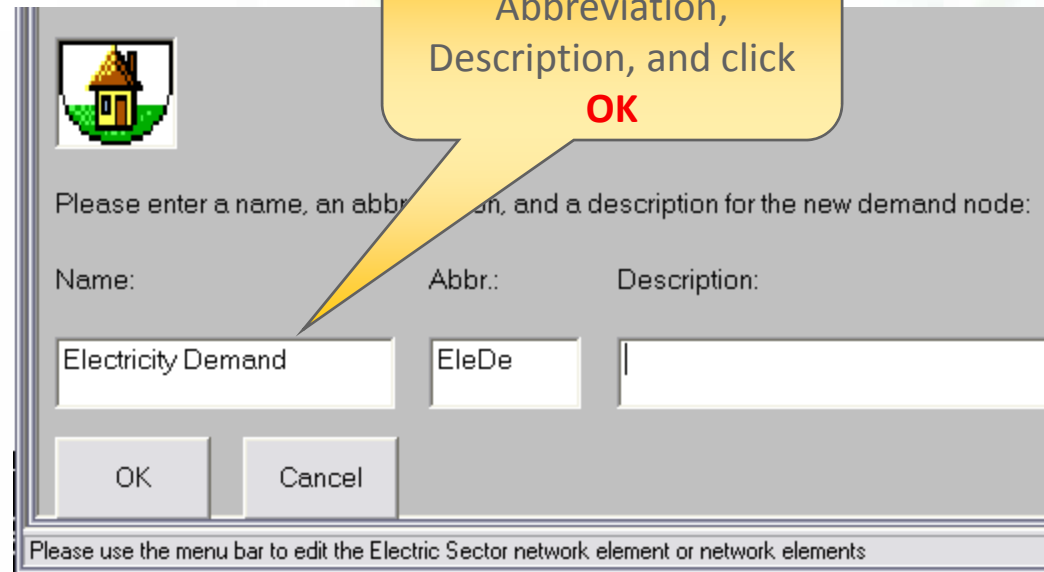
Step 7: Use the Node Pull-down Icon and Select the Node you Want to Include in the Sector



(1) Select **Demand Node** icon



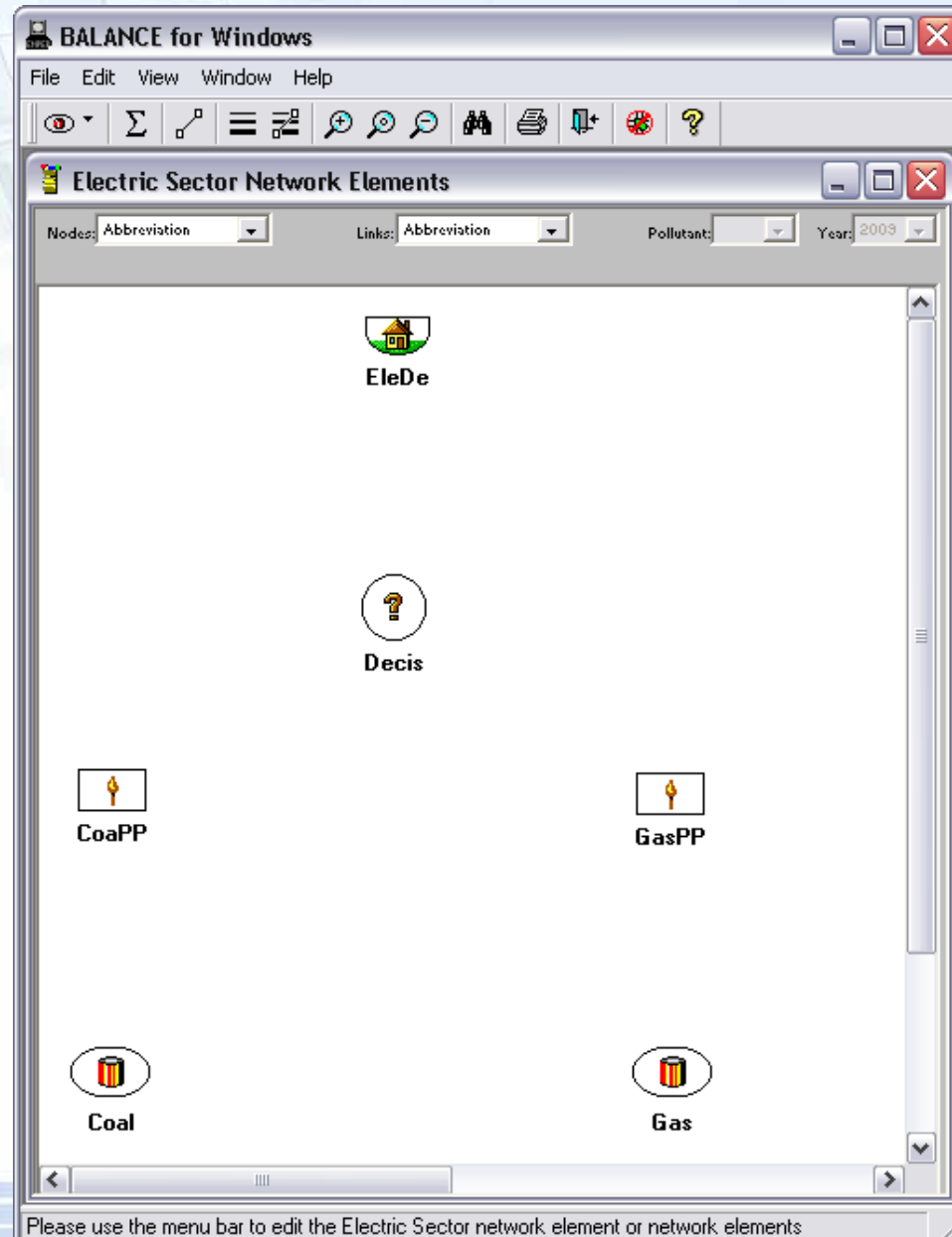
(2) Move the mouse to where you want to place the node and click



(3) Enter Name, Abbreviation, Description, and click **OK**

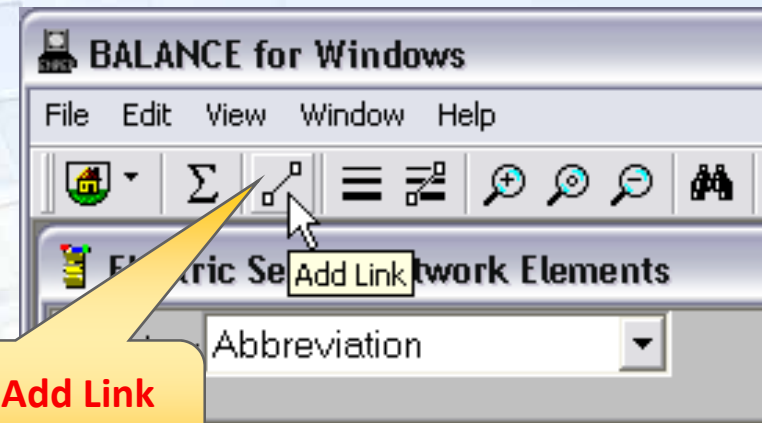
Step 8: Repeat Step 7 for all Nodes in the Network

- Allocation node
 - Name: Decision node
 - Abbreviation: Decis
- Conversion process node 1
 - Name: Coal power plant
 - Abbreviation: CoaPP
- Conversion process node 2
 - Name: Gas power plant
 - Abbreviation: GasPP
- Depletable resource node 1
 - Name: Coal resource
 - Abbreviation: Coal
- Depletable resource node 2
 - Name: Natural gas resource
 - Abbreviation: Gas



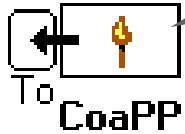
Step 9: Use the “Add Link” Icon in the Menu to Draw the Links and to Connect the Nodes

- Start at the bottom with the resources
- FROM – TO: Trace how energy flows from resource (bottom) to consumption (top)



(1) Click on **Add Link** icon

(3) Move the mouse to the finish node (TO) and click the node

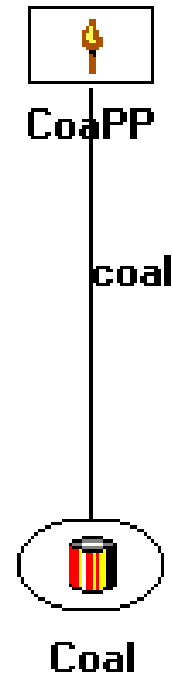


(2) Move the mouse to the starting node (FROM) and click the node

Name:	Abbr.:	Description:
coal	coal	

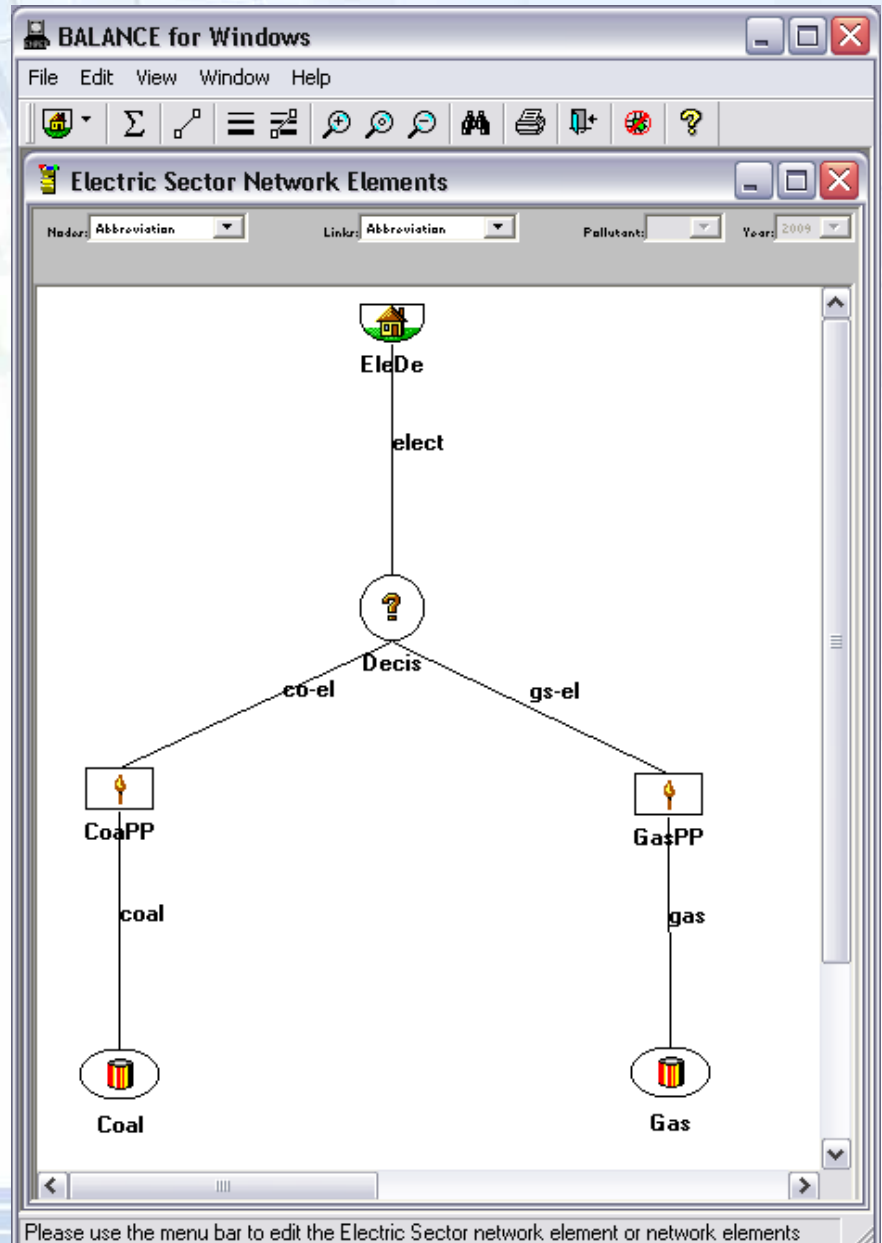
OK Cancel

(4) Enter Name, Abbreviation, Description (optional), and click **OK**

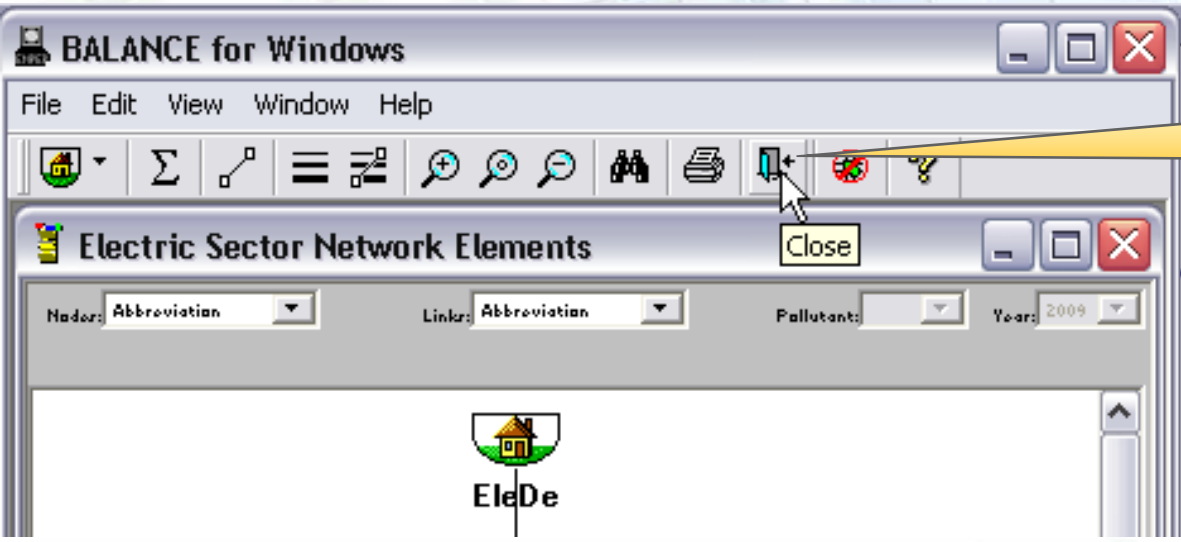


Step 10: Repeat Step 9 for all Links in the Network

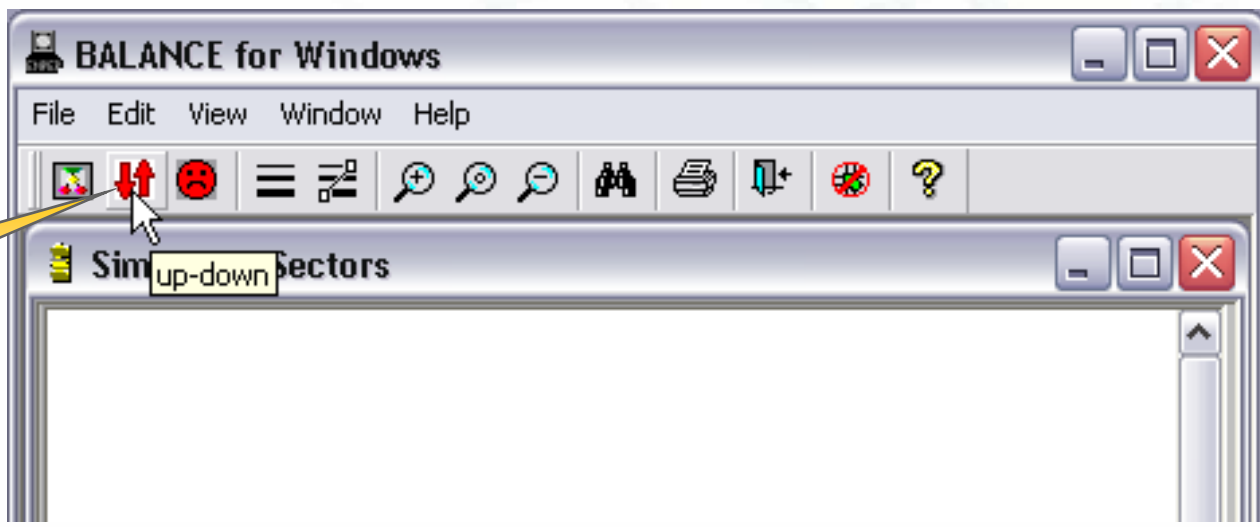
- Gas resource to gas power plant
 - Name: gas
 - Abbreviation: **gas**
- Coal power plant to decision node
 - Name: coal electricity
 - Abbreviation: **co-el**
- Gas power plant to decision node
 - Name: gas electricity
 - Abbreviation: **gs-el**
- Decision node to demand node
 - Name: electricity
 - Abbreviation: **elect**



Step 11: Validate Integrity of Network Structure



(1) Click on the **Close** icon to close the sector

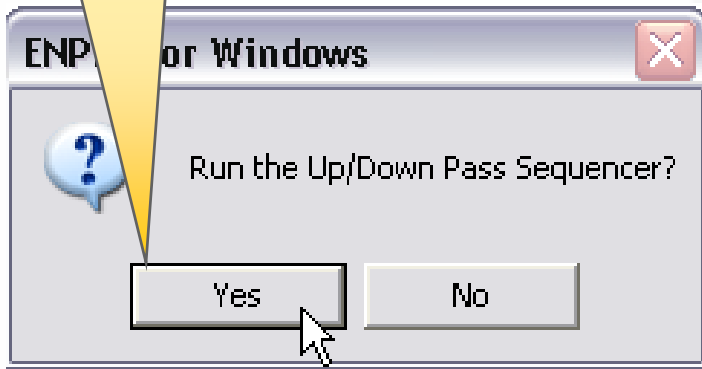


(2) Click on the **up-down** icon to run the validation

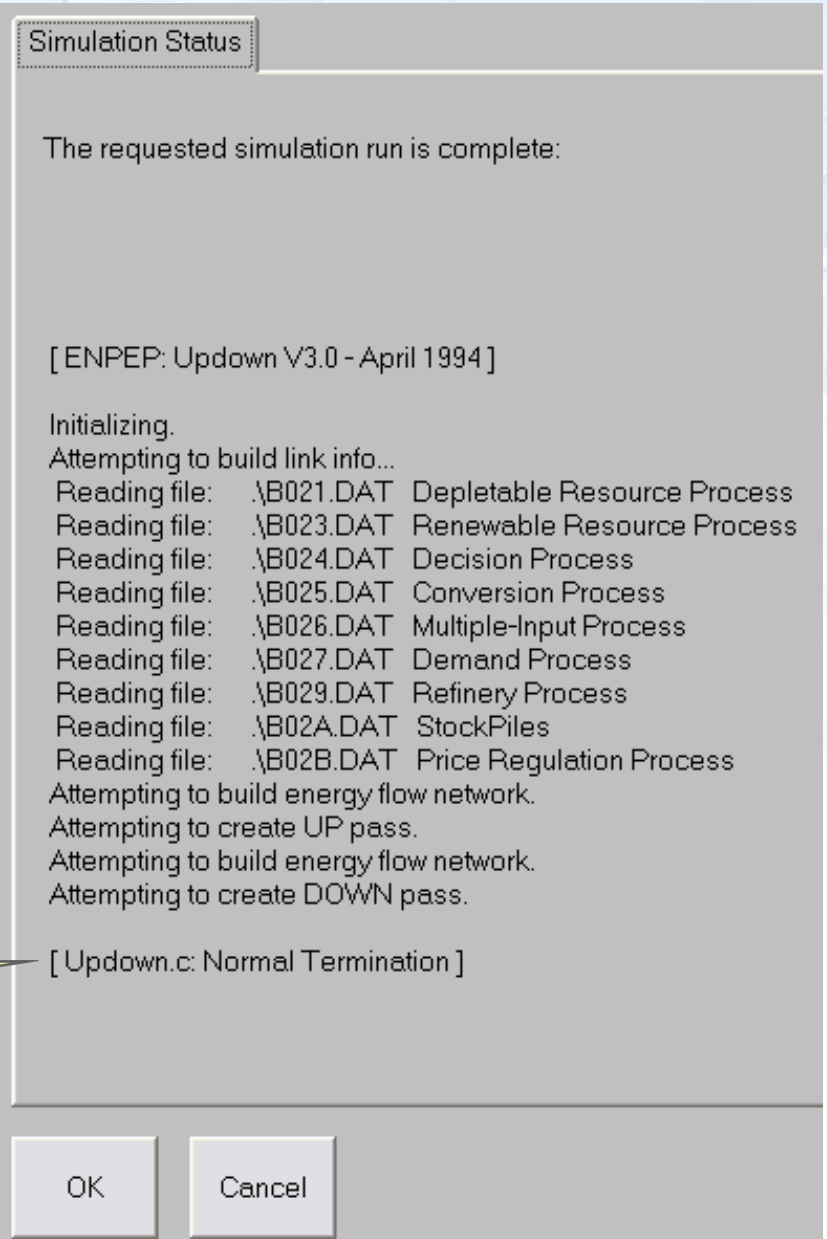


Step 11: Validate Integrity of Network Structure (cont'd)

(1) Click **Yes** to confirm



(2) Look for "Normal Termination" and then click **OK**



Step 12: Enter Input Data – Resource Nodes (Coal)

Technical Properties | Economic Properties | Emissions Properties | IPCC

Base Year Production (kboe)

Year	Capacity (kboe)
2009	<input type="text"/>
2010	<input type="text"/>
2011	<input type="text"/>
2012	<input type="text"/>
2013	<input type="text"/>
2014	<input type="text"/>

Coal consumption in 2009

Technical Properties | Economic Properties | Emissions Properties | IPCC

Year	Price Growth Rate (Fraction)	Curve Intercept (\$/boe)	Curve Slope	Curve Quadratic
2009	<input type="text" value="0.015"/>	<input type="text" value="9.000"/>	<input type="text"/>	<input type="text"/>
2010	<input type="text" value="0.015"/>			
2011	<input type="text" value="0.015"/>			
2012	<input type="text" value="0.015"/>			
2013	<input type="text" value="0.015"/>			
2014	<input type="text" value="0.015"/>			
2015	<input type="text" value="0.015"/>			
2016	<input type="text" value="0.015"/>			
2017	<input type="text" value="0.015"/>			
2018	<input type="text" value="0.015"/>			
2019	<input type="text" value="0.015"/>			
2020	<input type="text" value="0.015"/>			
2021	<input type="text" value="0.015"/>			
2022	<input type="text" value="0.015"/>			

Price of coal in 2009 and expected annual price increase



Step 12: Enter Input Data – Resource Nodes (Gas)

Technical Properties
 Economic Properties
 Emissions Properties
 IPCC

Base Year Production (kboe)

Year	Capacity (kboe)
2009	<input type="text"/>
2010	<input type="text"/>
2011	<input type="text"/>
2012	<input type="text"/>
2013	<input type="text"/>
2014	<input type="text"/>

Gas consumption in 2009

Technical Properties
 Economic Properties
 Emissions Properties
 IPCC

Year	Price Growth Rate (Fraction)	Curve Intercept (\$/boe)	Curve Slope	Curve Quadratic
2009	<input type="text" value="0.010"/>	<input type="text" value="20.000"/>	<input type="text"/>	<input type="text"/>
2010	<input type="text" value="0.010"/>			
2011	<input type="text" value="0.010"/>			
2012	<input type="text" value="0.010"/>			
2013	<input type="text" value="0.010"/>			
2014	<input type="text" value="0.010"/>			
2015	<input type="text" value="0.010"/>			
2016	<input type="text" value="0.010"/>			
2017	<input type="text" value="0.010"/>			
2018	<input type="text" value="0.010"/>			
2019	<input type="text" value="0.010"/>			
2020	<input type="text" value="0.010"/>			
2021	<input type="text" value="0.010"/>			
2022	<input type="text" value="0.010"/>			

Price of gas in 2009 and expected annual price increase



Step 13: Enter Input Data – Conversion Nodes (Coal Power Plant)

Technical Properties					Economic Properties					Emissions Properties				
		Single Plant		All Plants		Typical		Output/Input						
Year		Output Capacity (kboe)		Output Capacity (kboe)		Capacity Factor (Fraction)		Ratio (Fraction)						
2009		2,716.000		999,999.000		0.750		0.380						
2010														
2011														
2012														

Technical Properties					Economic Properties					Emissions Properties				
		Single Plant Capital		Operating and		Life		Interest Rate						
Year		Investment (\$1000)		Maintenance Cost (\$/boe)		Expectancy (Years)		Rate (Fraction)						
2009		730,000.000		6.900		30.00		0.100						
2010														
2011														
2012														
2013														

Step 13: Enter Input Data – Conversion Nodes (Gas Power Plant)

Technical Properties		Economic Properties	Emissions Properties		
Year	Single Plant Output Capacity (kboe)	All Plants Output Capacity (kboe)	Typical Capacity Factor (Fraction)	Output/Input Ratio (Fraction)	
2009	2,716.000	999,999.000	0.750	0.510	
2010					
2011					
2012					
2013					

Technical Properties		Economic Properties	Emissions Properties		
Year	Single Plant Capital Investment (\$1000)	Operating and Maintenance Cost (\$/boe)	Life Expectancy (Years)	Interest Rate (Fraction)	
2009	328,000.000	3.100	30.00	0.100	
2010					
2011					
2012					
2013					



Step 14: Enter Input Data – Decision/Allocation Node

Technical Properties		Economic Properties			
Year	Input Link Abbreviation	Priority	Premium Multiplier	Output Link Abbreviation	Base Year Split (Fraction)
2009	co-el			elect	1.0000
	gs-el				
2010	co-el			Sum:	1
	gs-el				
2011	co-el				
	gs-el				

Technical Properties		Economic Properties			
Year	Price Sensitivity	Lag Parameter (Fraction)	Electric Grid link	Stockpile	Run MSHARE
2009	3.000	0.100	<input type="text" value=""/>	<input type="text" value=""/>	<input type="checkbox"/>

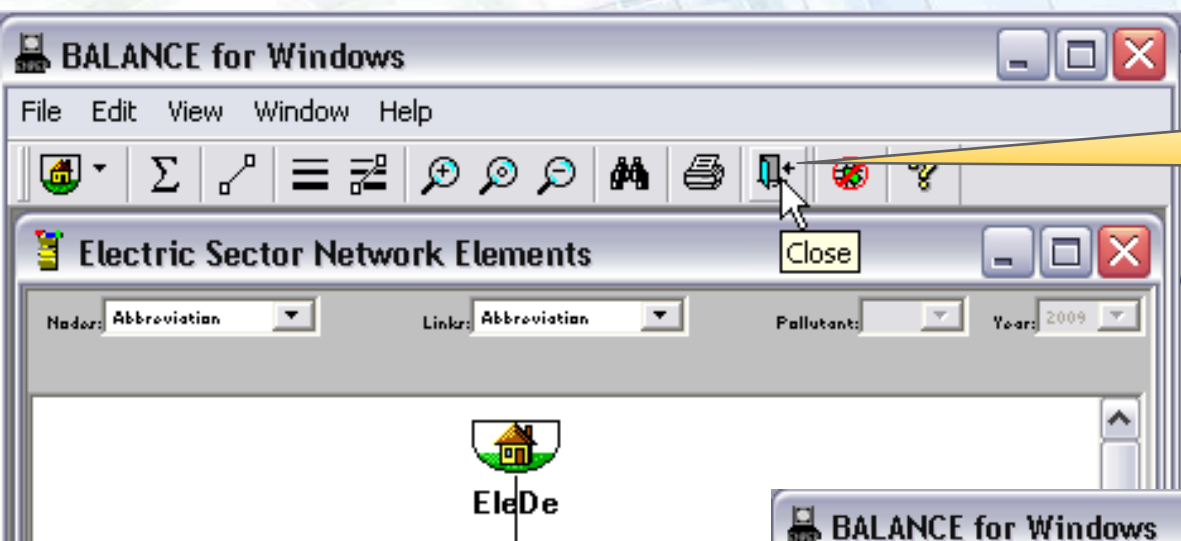


Step 15: Enter Input Data – Demand Node

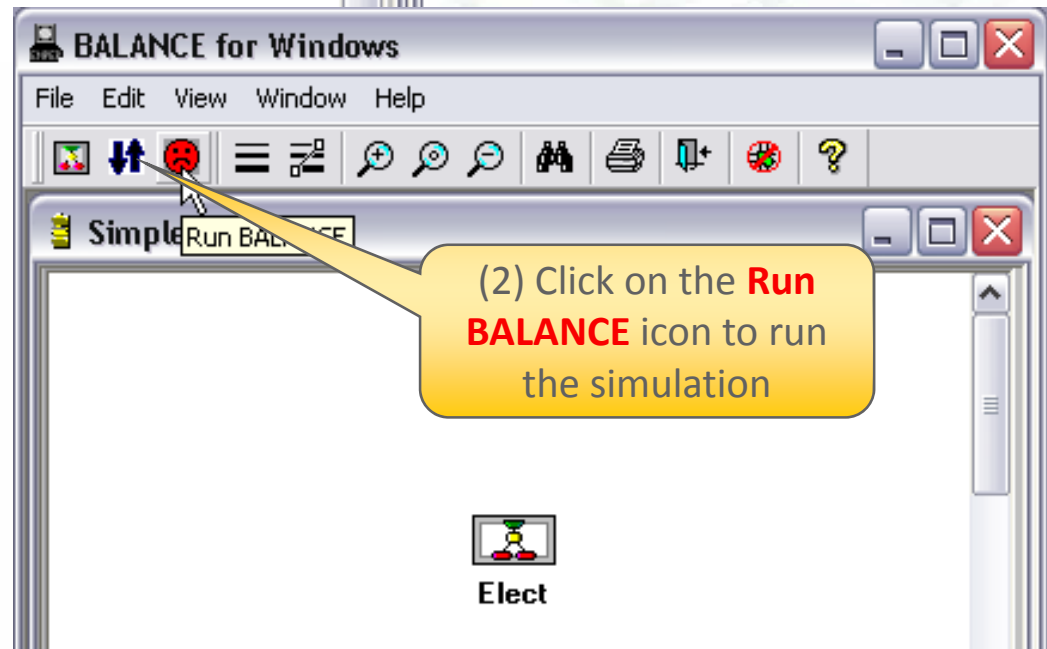
Economic Properties		Emissions Properties	
Year	Growth Rate (Fraction)	Elasticity	Type
2009	0.020	0	Non Linear
2010	0.020		
2011	0.020		
2012	0.020		
2013	0.020		
2014	0.020		
2015	0.020		
2016	0.020		
2017	0.020		
2018	0.020		
2019	0.020		
2020	0.020		
2021	0.020		
2022	0.020		



Step 16: Run ENPEP-BALANCE

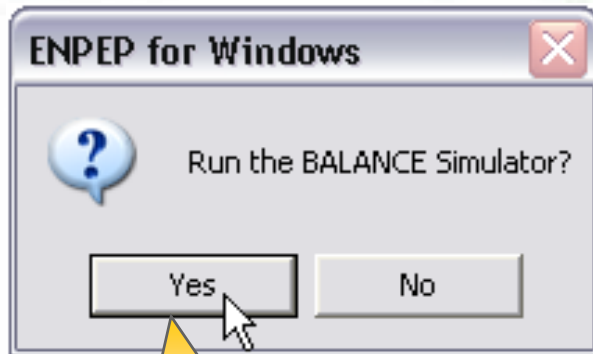


(1) Click on the **Close** icon to close the sector



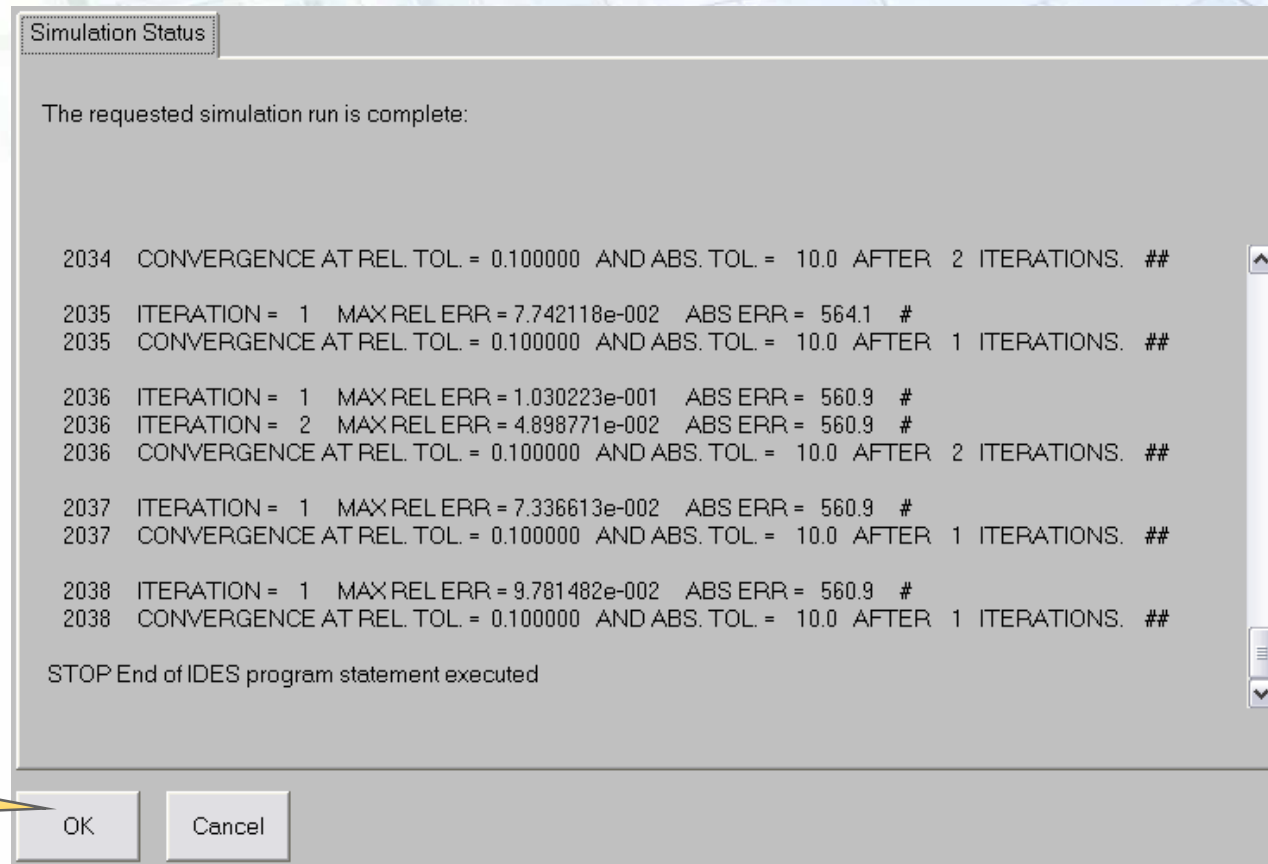
(2) Click on the **Run BALANCE** icon to run the simulation

Step 16: Run ENPEP-BALANCE (cont'd)

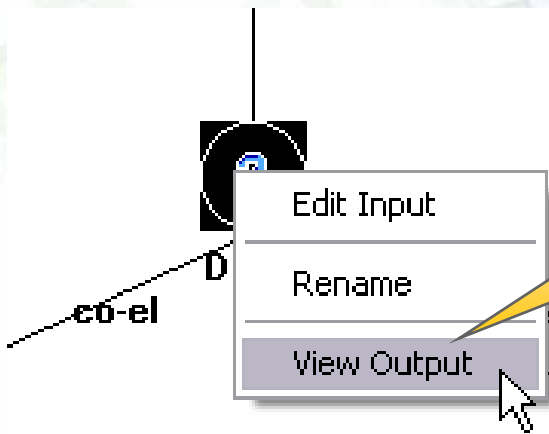


(1) Click **YES** to confirm

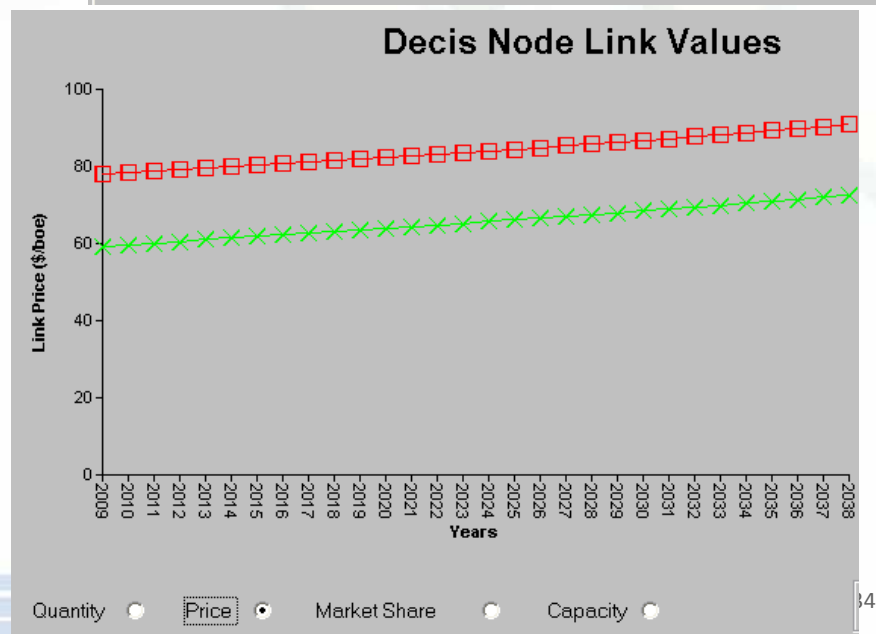
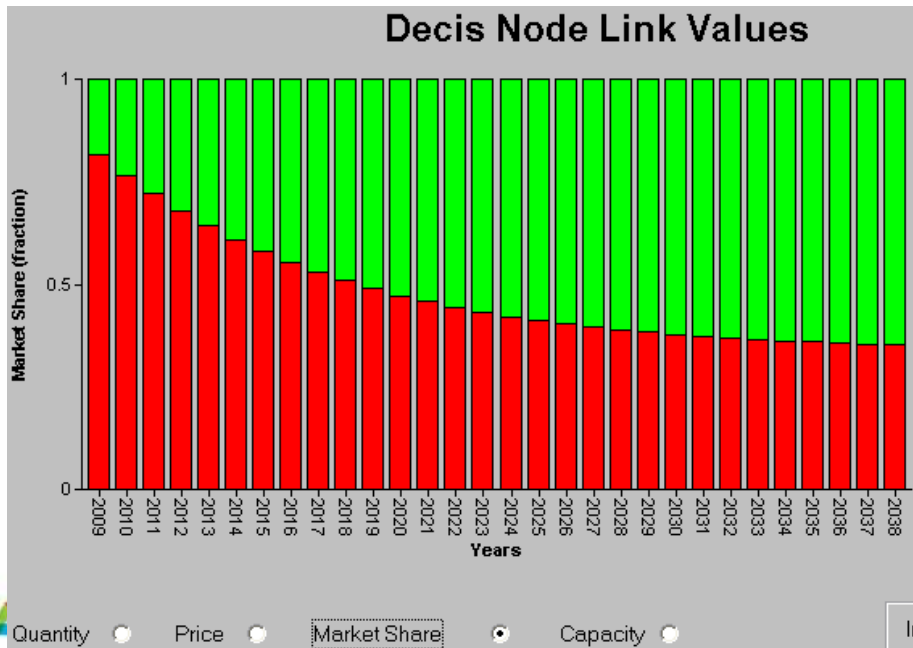
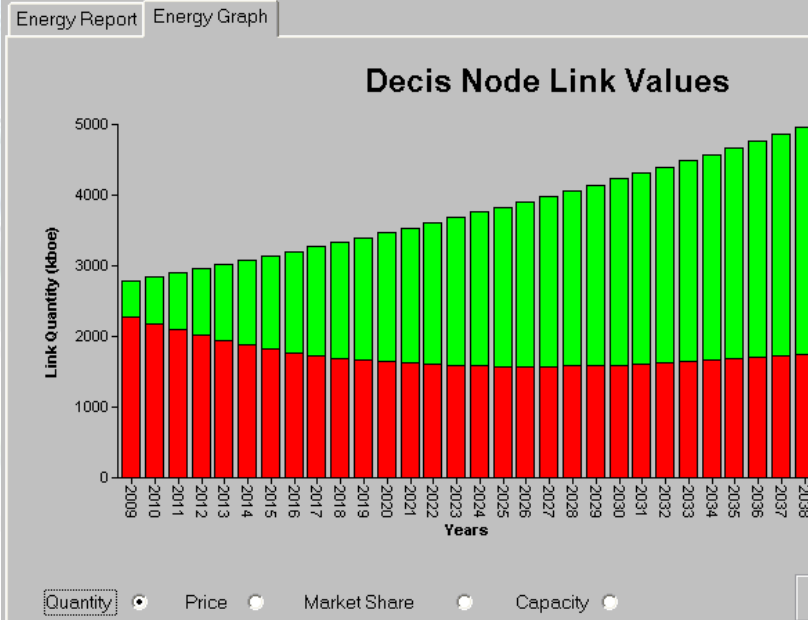
(2) If no warnings and error messages, click **OK**



Step 17: Review Results at Decision/Allocation Node



(1) Select decision node, **RIGHT-CLICK**, and choose **VIEW OUTPUT**



Run the Following Scenarios and Interpret the Results

- Higher price sensitivity (Decision/Allocation Node): 13

Technical Properties		Economic Properties	
Year	Price Sensitivity	Lag Parameter (Fraction)	Electric Grid link
2009	13.000	0.100	<input type="checkbox"/>

- Different gas price scenario: 1% increase until 2015, 4% starting in 2016

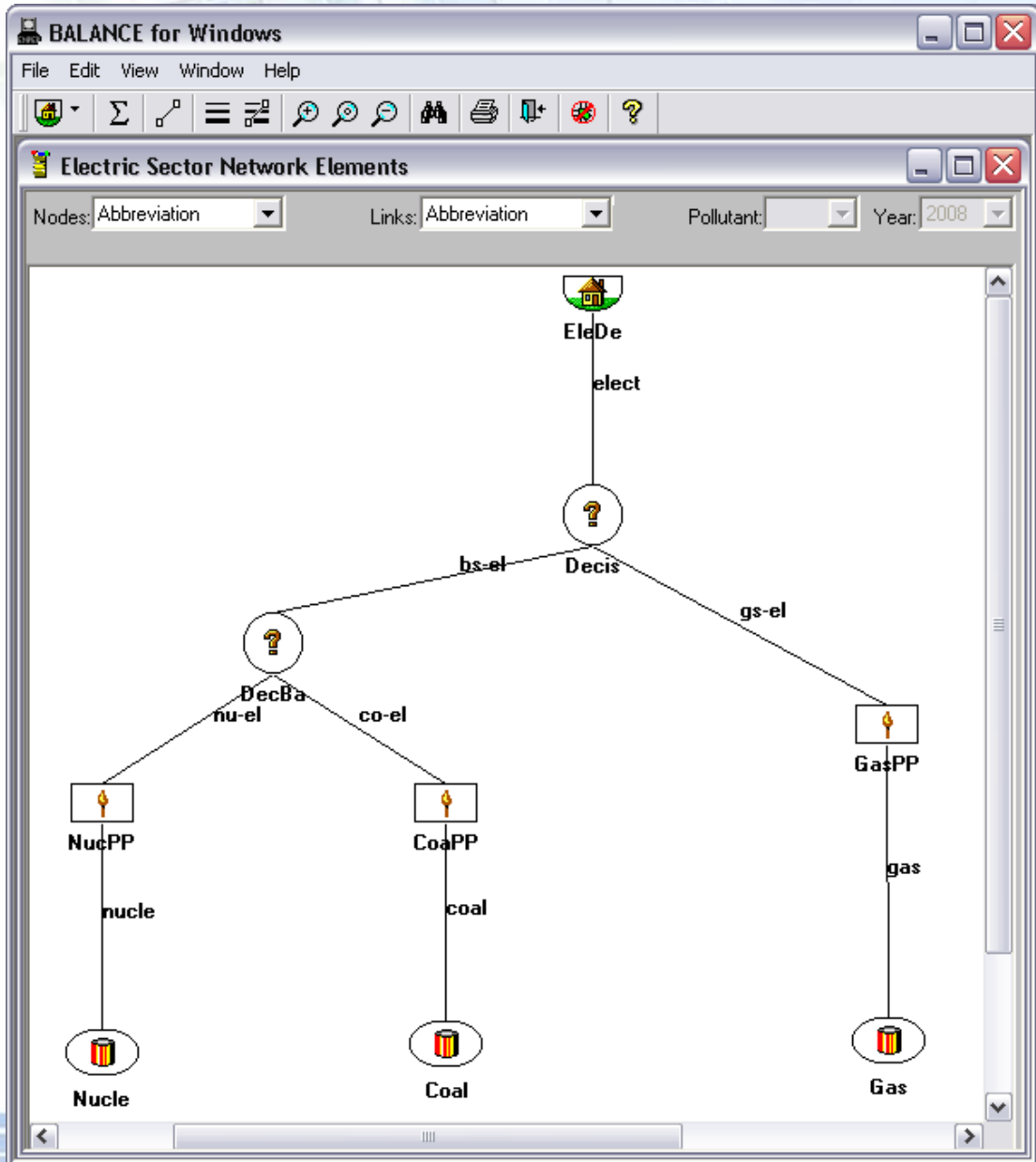
- Effect of financing terms, for example gas power plant: Interest rate of 25%

Technical Properties		Economic Properties		Emissions Properties
Year	Price Growth Rate	Curve Intercept (\$/boe)		
2009	0.010	20.000		
2010	0.010			
2011	0.010			
2012	0.010			
2013	0.010			
2014	0.010			
2015	0.010			
2016	0.040			
2017	0.040			
2018	0.040			
2019	0.040			
2020	0.040			
2021	0.040			
2022	0.040			

Technical Properties		Economic Properties		Emissions Properties	
Year	Single Plant Capital Investment (\$1000)	Operating and Maintenance Cost (\$/boe)	Life Expectancy (Years)	Interest Rate (Fraction)	
2009	328,000.000	3.100	30.00	0.250	
2010					



New Nuclear Power with Different Network Configuration



Step 1: Enter Input Data – Resource Nodes (Nuclear Fuel)

Technical Properties
 Economic Properties
 Emissions Properties
 IPCC

Base Year Production (kboe)

Year	Capacity (kboe)
2009	<input type="text"/>
2010	<input type="text"/>
2011	<input type="text"/>
2012	<input type="text"/>
2013	<input type="text"/>
2014	<input type="text"/>

Technical Properties
 Economic Properties
 Emissions Properties
 IPCC

Year	Price Growth Rate	Curve Intercept (\$/boe)	Curve Slope	Curve Quadratic
2009	<input type="text" value="0.010"/>	<input type="text" value="2.500"/>	<input type="text"/>	<input type="text"/>
2010	<input type="text" value="0.010"/>			
2011	<input type="text" value="0.010"/>			
2012	<input type="text" value="0.010"/>			
2013	<input type="text" value="0.010"/>			
2014	<input type="text" value="0.010"/>			
2015	<input type="text" value="0.010"/>			
2016	<input type="text" value="0.010"/>			
2017	<input type="text" value="0.010"/>			



Step 2: Enter Input Data – Conversion Nodes (Nuclear Power Plant)

Technical Properties				
Economic Properties				
Emissions Properties				
Year	Single Plant Output Capacity (kboe)	All Plants Output Capacity (kboe)	Typical Capacity Factor (Fraction)	Output/Input Ratio (Fraction)
2009	7,604.000		0.900	0.330
2010				
2011				
2012				
2013				
2014				
2015				
2016				
2017				
2018				
2019		999,999.000		
2020				
2021				

Technical Properties				
Economic Properties				
Emissions Properties				
Year	Single Plant Capital Investment (\$1000)	Operating and Maintenance Cost (\$/boe)	Life Expectancy (Years)	Interest Rate (Fraction)
2009	3,500,000.000	0.800	40.00	0.100
2010				
2011				



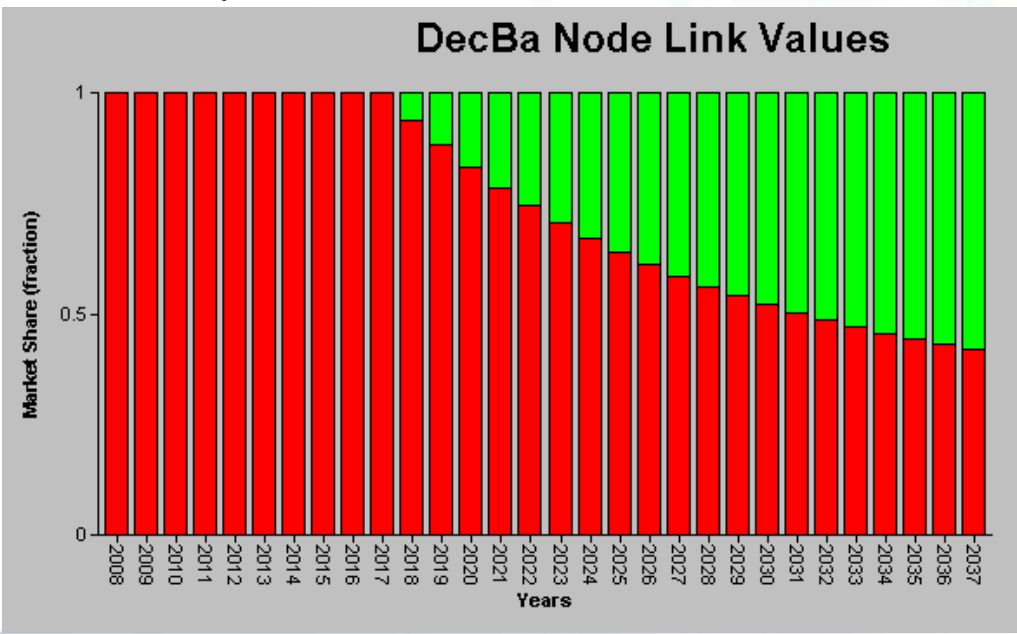
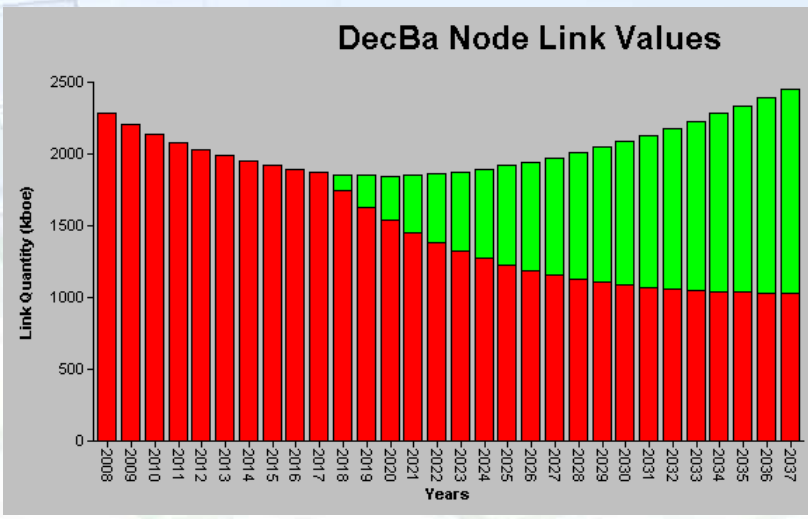
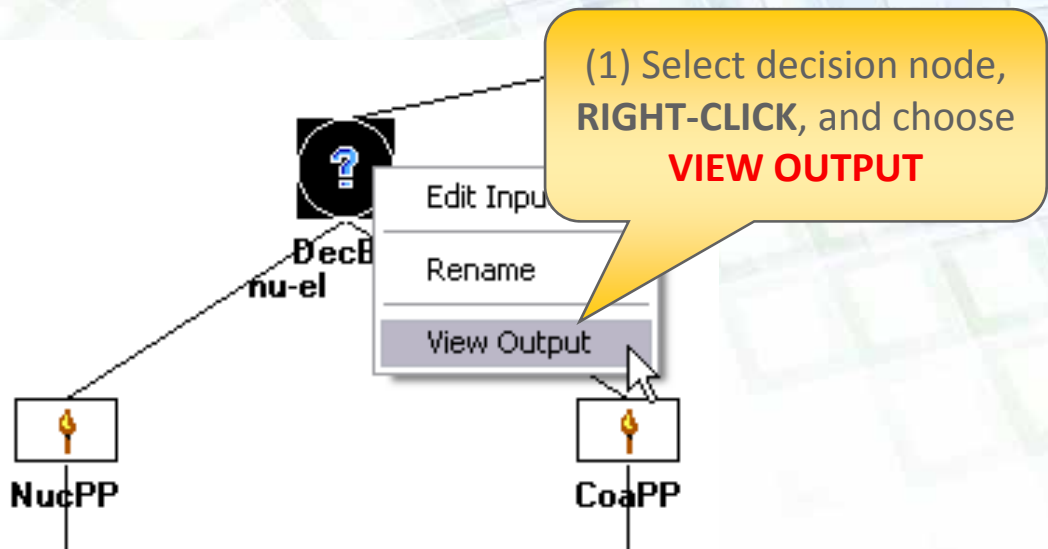
Step 3: Enter Input Data – Decision/Allocation Node

Technical Properties		Economic Properties			
Year	Input Link Abbreviation	Priority	Premium Multiplier	Output Link Abbreviation	Base Year Split (Fraction)
2009	co-el			bs-el	1.0000
	nu-el				
2010	co-el			Sum:	1
	nu-el				

Technical Properties		Economic Properties	
Year	Price Sensitivity	Lag Parameter (Fraction)	Electric Grid link
2009	3.000	0.100	▼



Step 4: Review Results at Decision/Allocation Node



Run the Following Scenarios and Interpret the Results

- Effect of financing terms, for example nuclear power plant: Interest rate of 18%

Technical Properties		Economic Properties	Emissions Properties	
Year	Single Plant Capital Investment (\$1000)	Operating and Maintenance Cost (\$/boe)	Life Expectancy (Years)	Interest Rate (Fraction)
2009	3,500,000.000	0.800	40.00	0.180
2010				
2011				

- Effect of carbon price

Technical Properties		Economic Properties	Emissions Properties	
Year	Pollutant Abbreviation	Uncontrolled Emission Factor Input Based (kg/GJ)	Chemical Scale	Emissions Tax (\$/tonne)
2009	CH4			
	CO2	100.000	Carbon	30.00

Coal plant; emission factor and carbon price

Technical Properties		Economic Properties	Emissions Properties	
Year	Pollutant Abbreviation	Uncontrolled Emission Factor Input Based (kg/GJ)	Chemical Scale	Emissions Tax (\$/tonne)
2009	CH4			
	CO2	50.000	Carbon	30.00

Gas plant; emission factor and carbon price

