Demo/Work Session Developing a Simple Energy Network

Workshop on Developing National Long-Range Nuclear Energy Strategies

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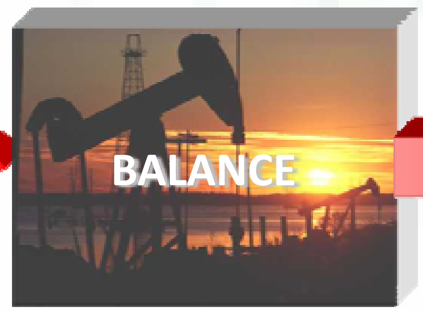
Introductory Points

- 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

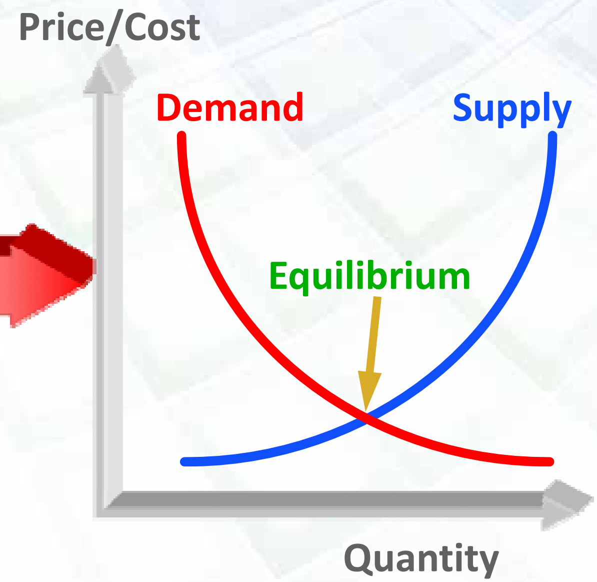
ENPEP-BALANCE Determines the Equilibrium Supply/Demand Balance of the Energy System

INPUT

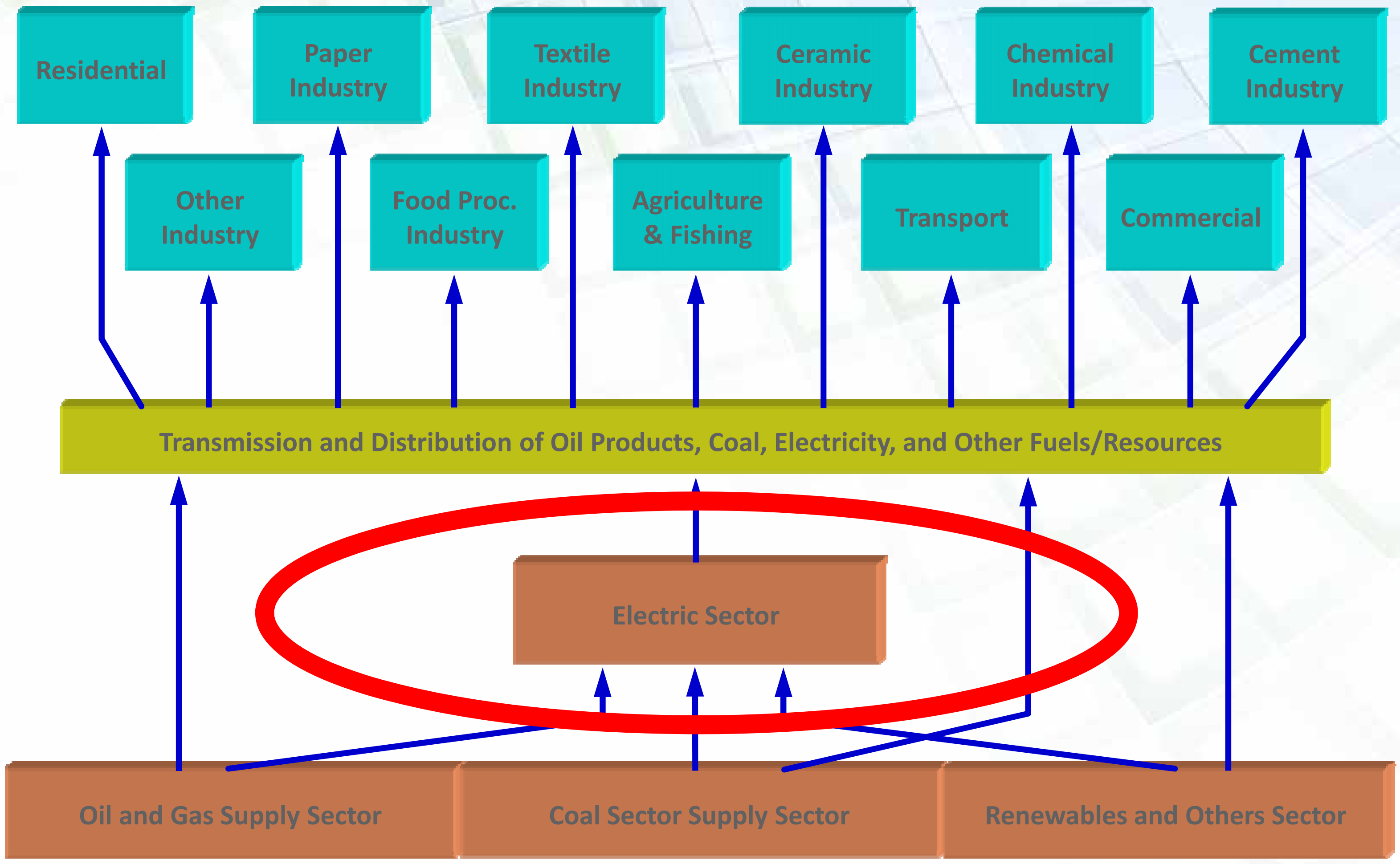
- Energy system structure
- Base year energy flows and prices
- Energy demand growth projections
- Technical and policy constraints



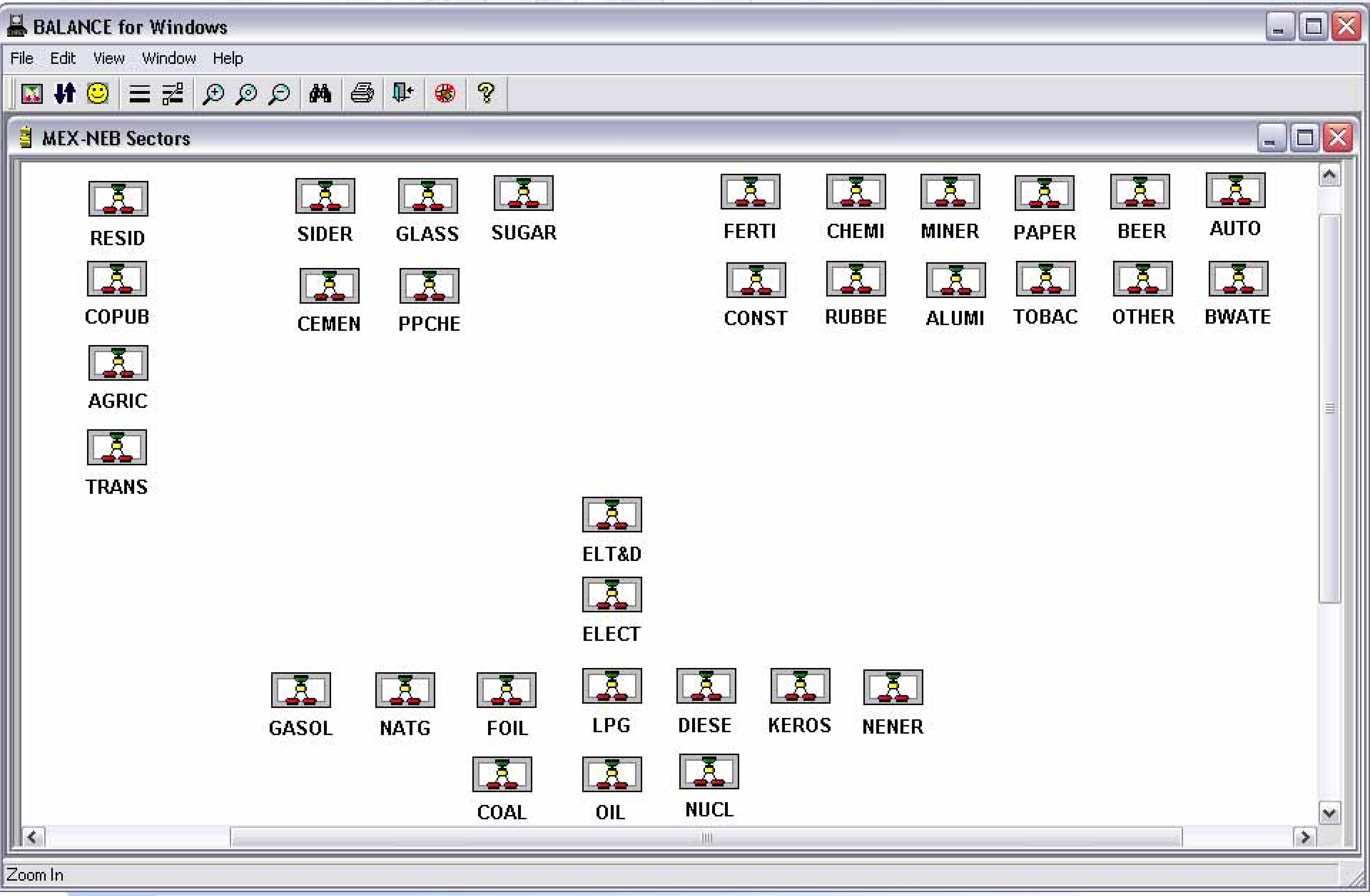
OUTPUT



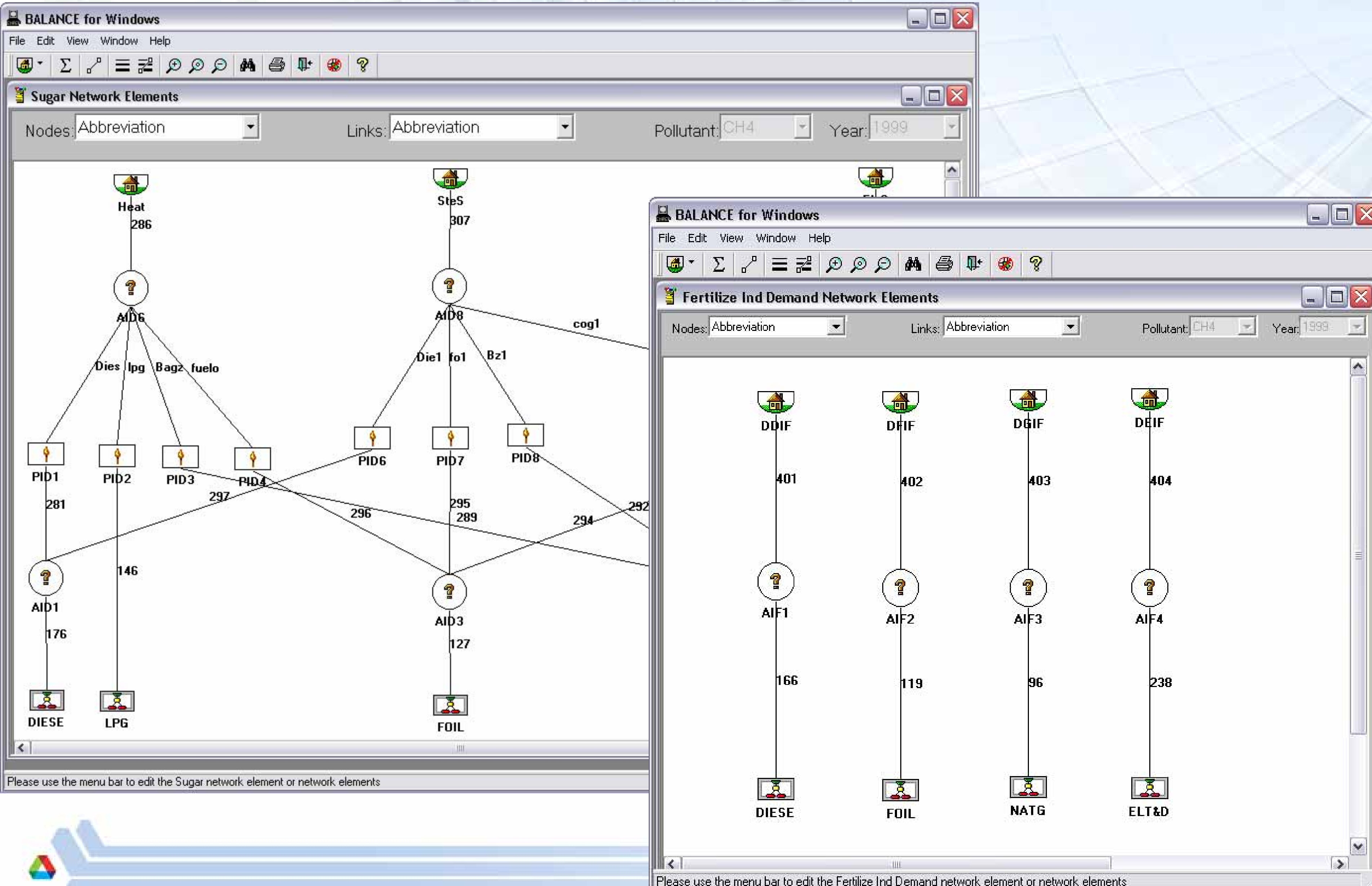
ENPEP-BALANCE Uses an Energy Network to Simulate Energy Markets (We will Focus on Electricity ONLY)



Networks are Organized into Sectors



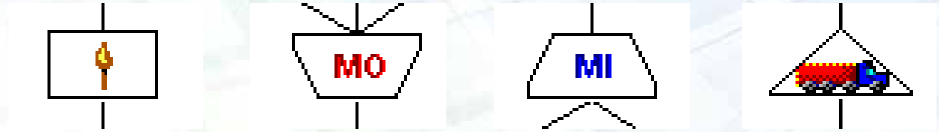
Network Sectors Consist of Nodes and Links



The Following Node Types are Available to Model Different Energy Activities

- Demand

- Conversion Processes

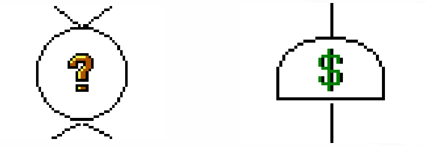


Single In-/Output | Multi Output | Multi Input | Transport

- Resource Processes

Depletable | Renewable

- Economic Processes

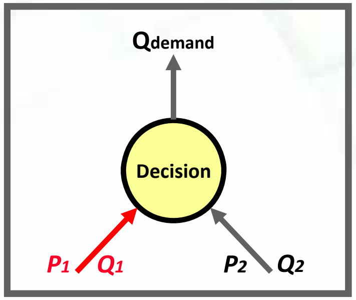


Decision/Allocation | Pricing

- 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



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

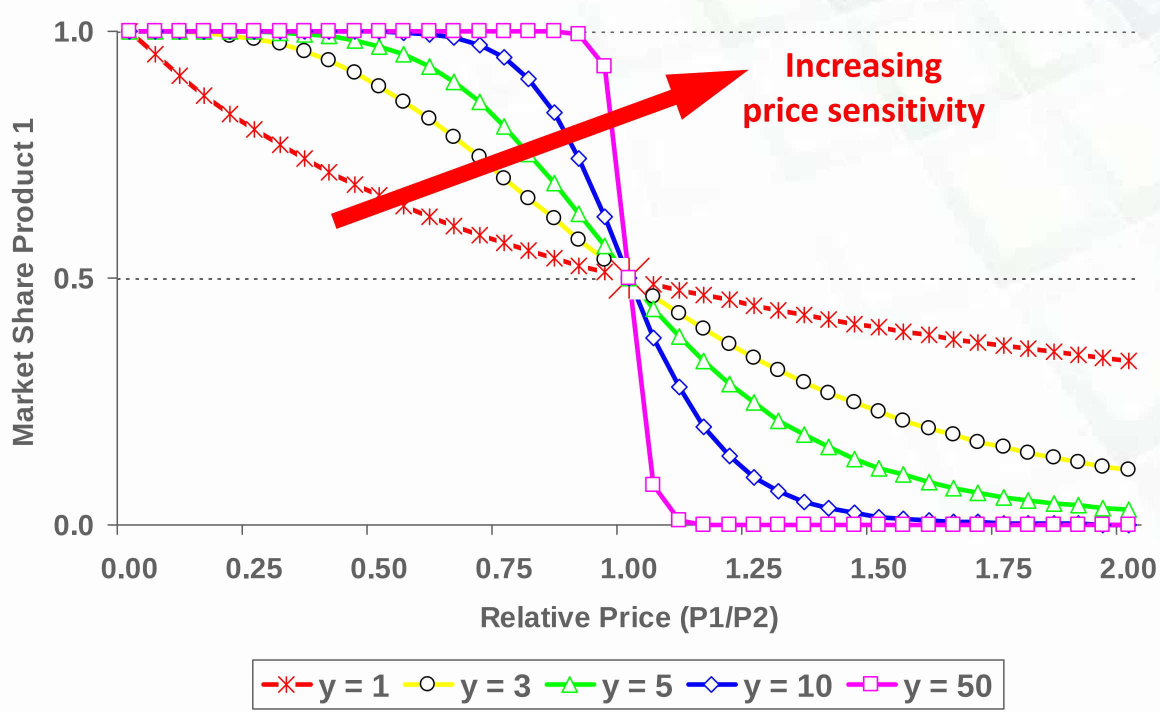
γ price sensitivity for this decision process

MS: market share

P: price

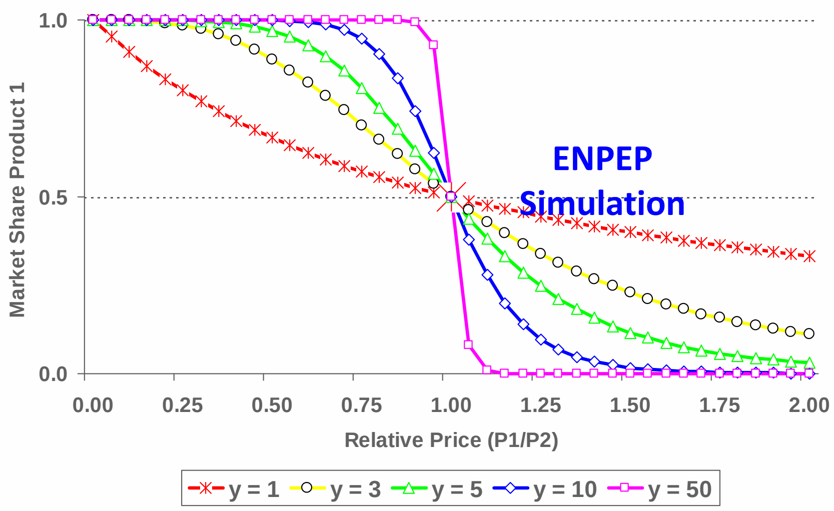
PM: premium multiplier

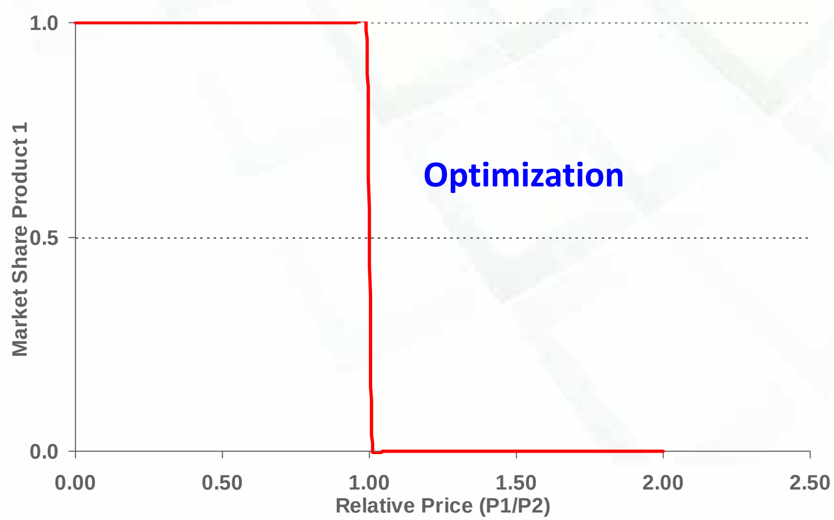
Q: quantity



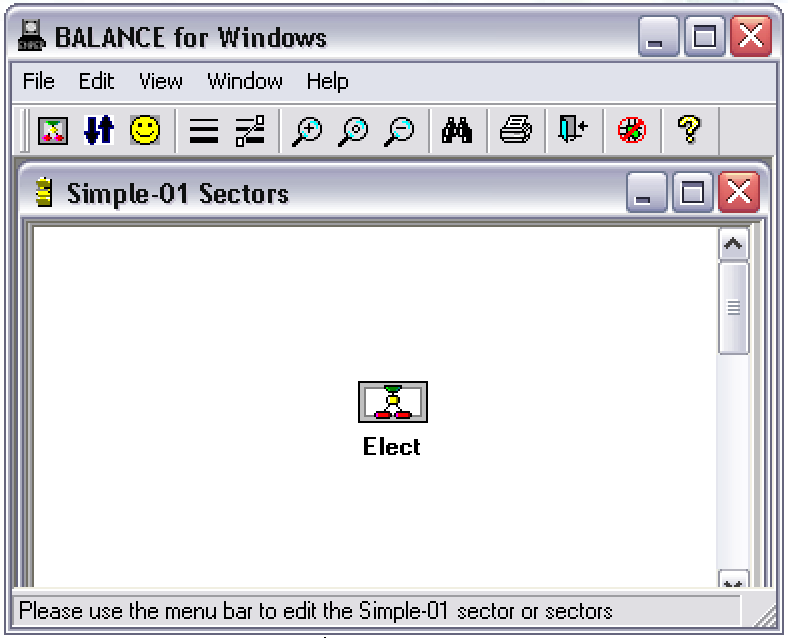
The ENPEP-BALANCE Nonlinear Equilibrium Algorithm is Based on Decentralized Decision Making

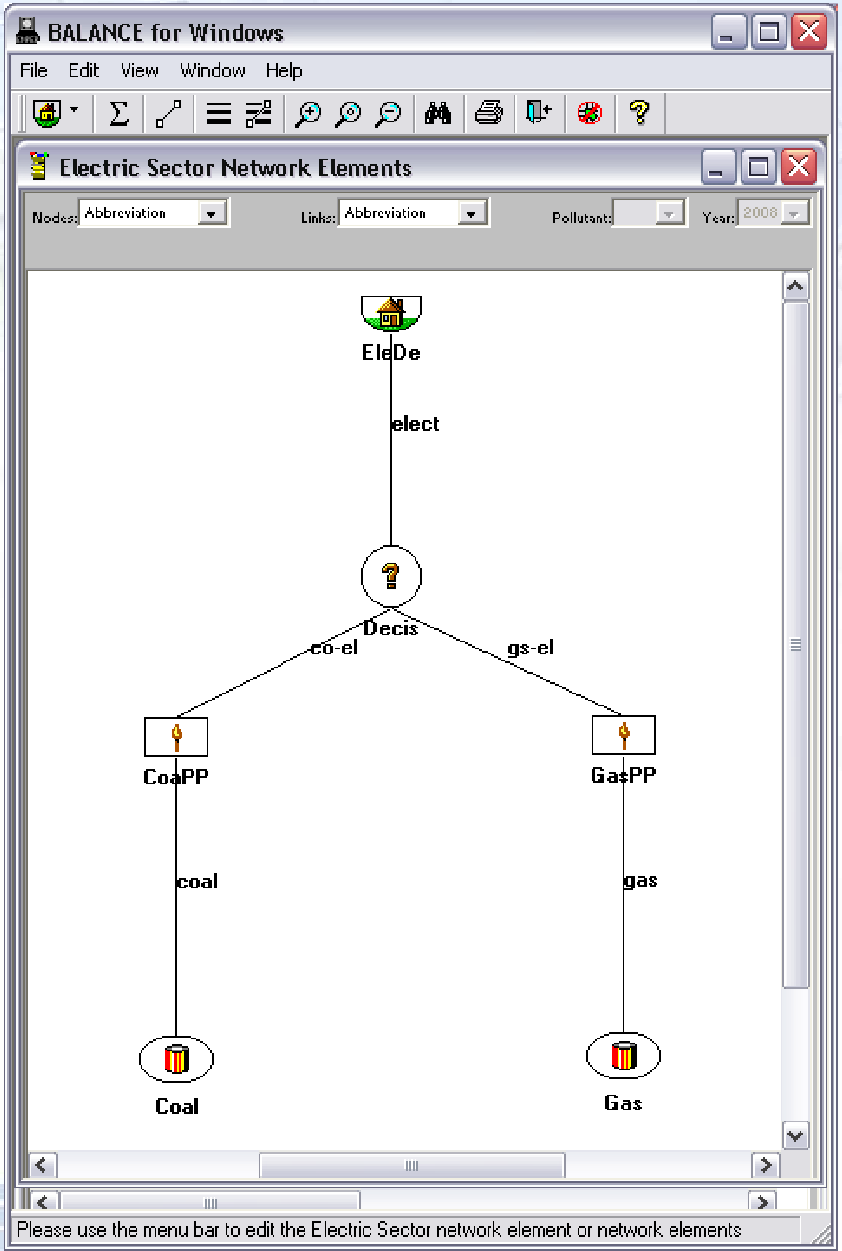
- Market share calculation assumes "ideal market" subject to government policies, fuel availability, and market constraints
- A lag factor accounts for delays in capital stock turnover
- The result is a nonlinear, market-based equilibrium solution within policy constraints, not a simple, linear optimization
- 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



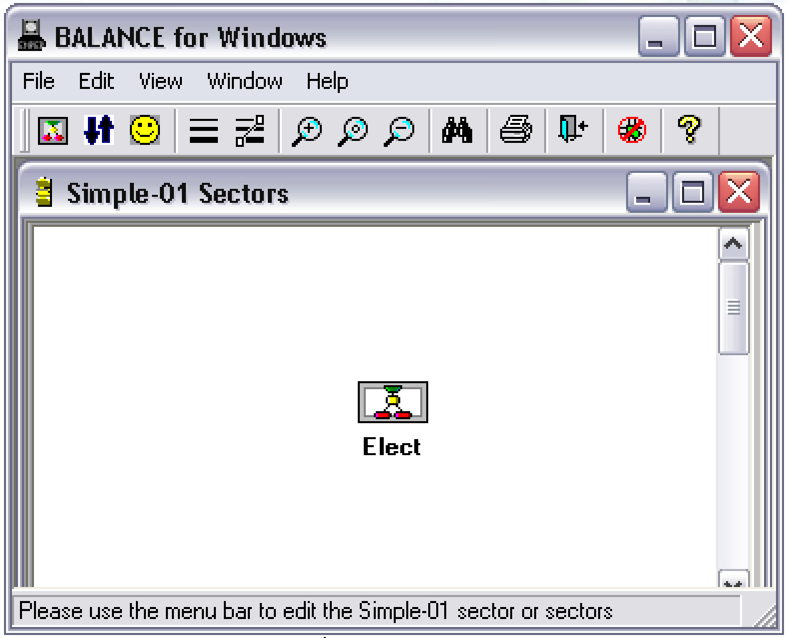


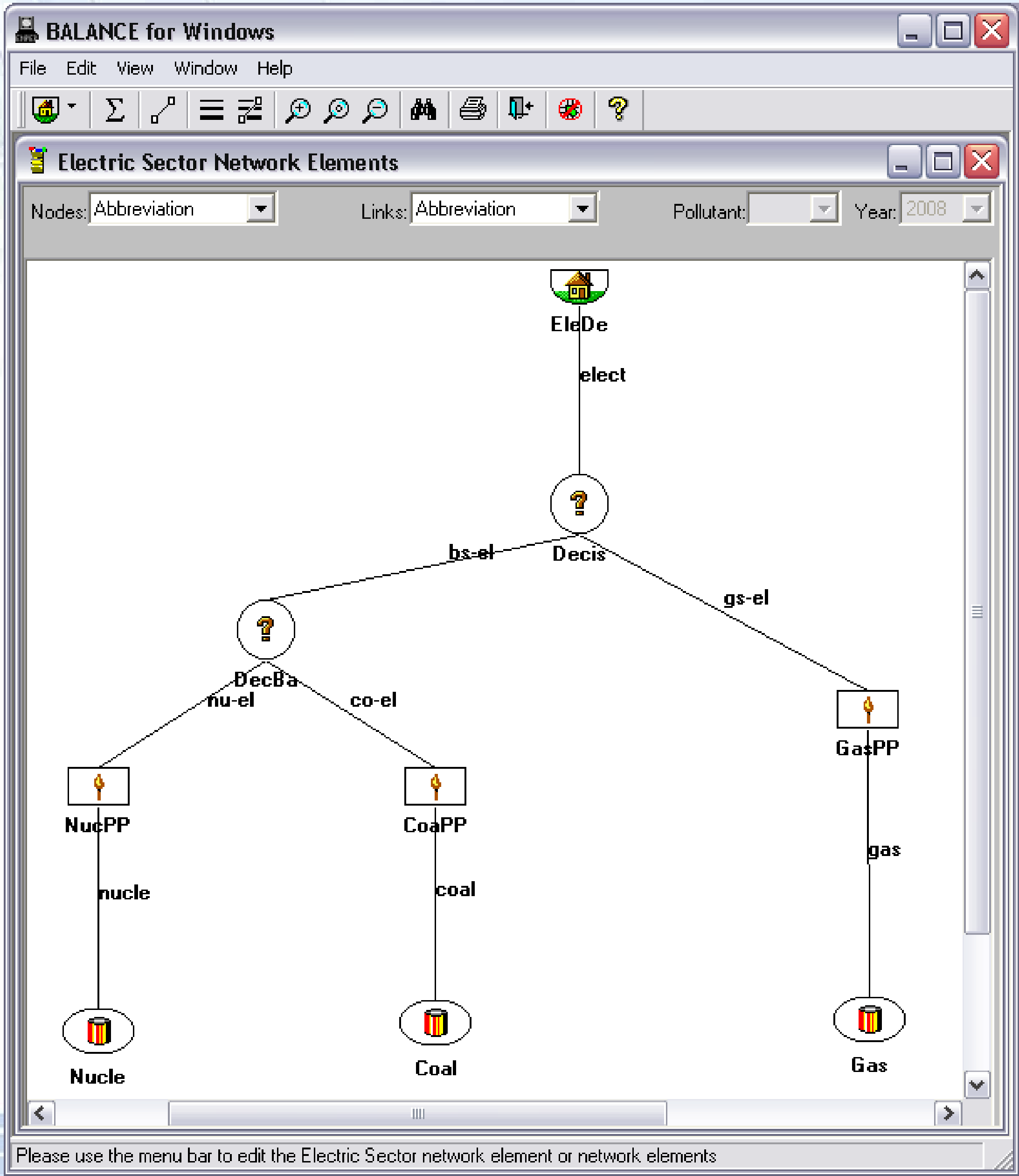
Network for our Simple Case Study – We will Start with One Sector (Electric) and 2 Power Plants





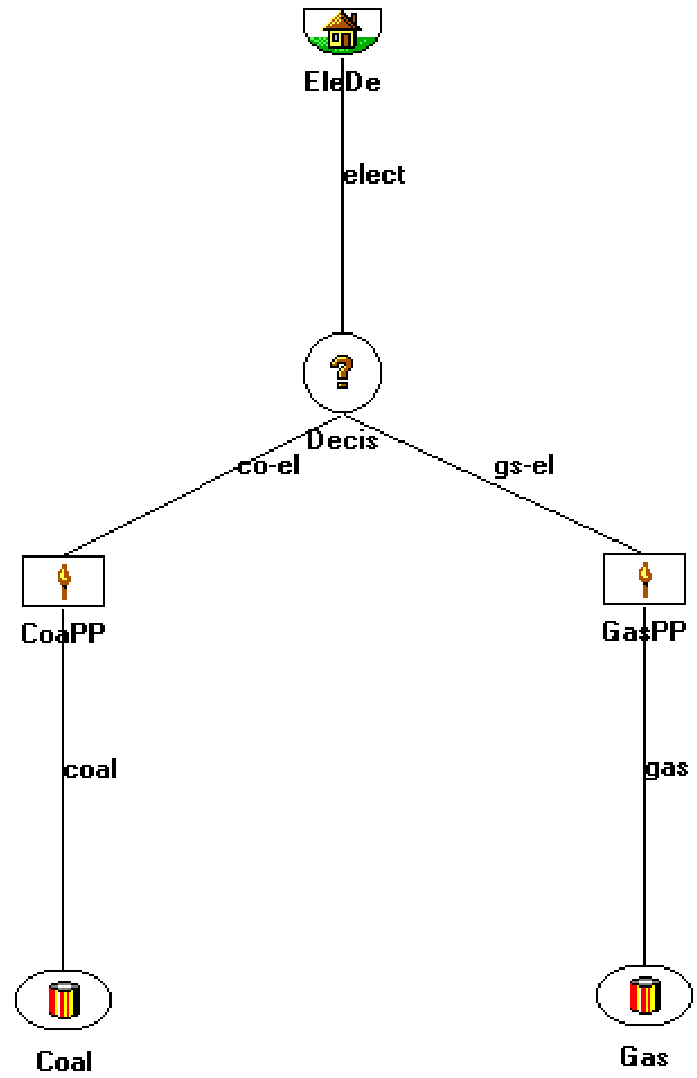
Later, we will Add one more Technology to the Mix and Change the Configuration Slightly





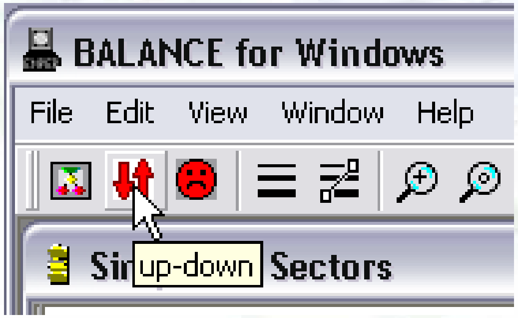
Configuration of the Simple Case Study

- 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

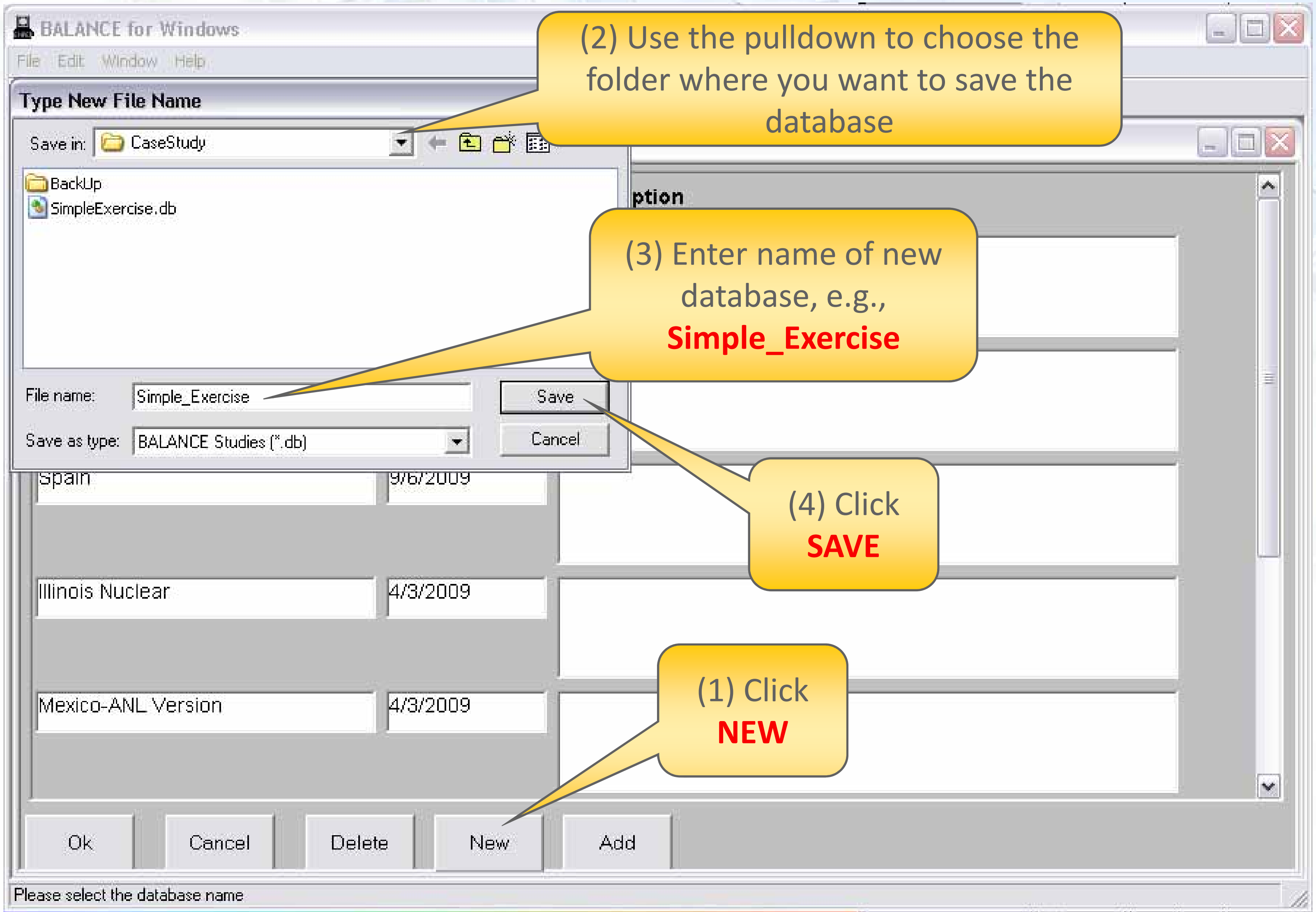
- Prepare the power system structure (see Steps 1 – 10 on following slides)
  - Draw the system using nodes and links
  - Label each system element
    - Each link and node has a name and abbreviation
- Execution Step 1: Validate network structure
  - Click on "**up-down**"
  - Necessary when arrows are **RED**



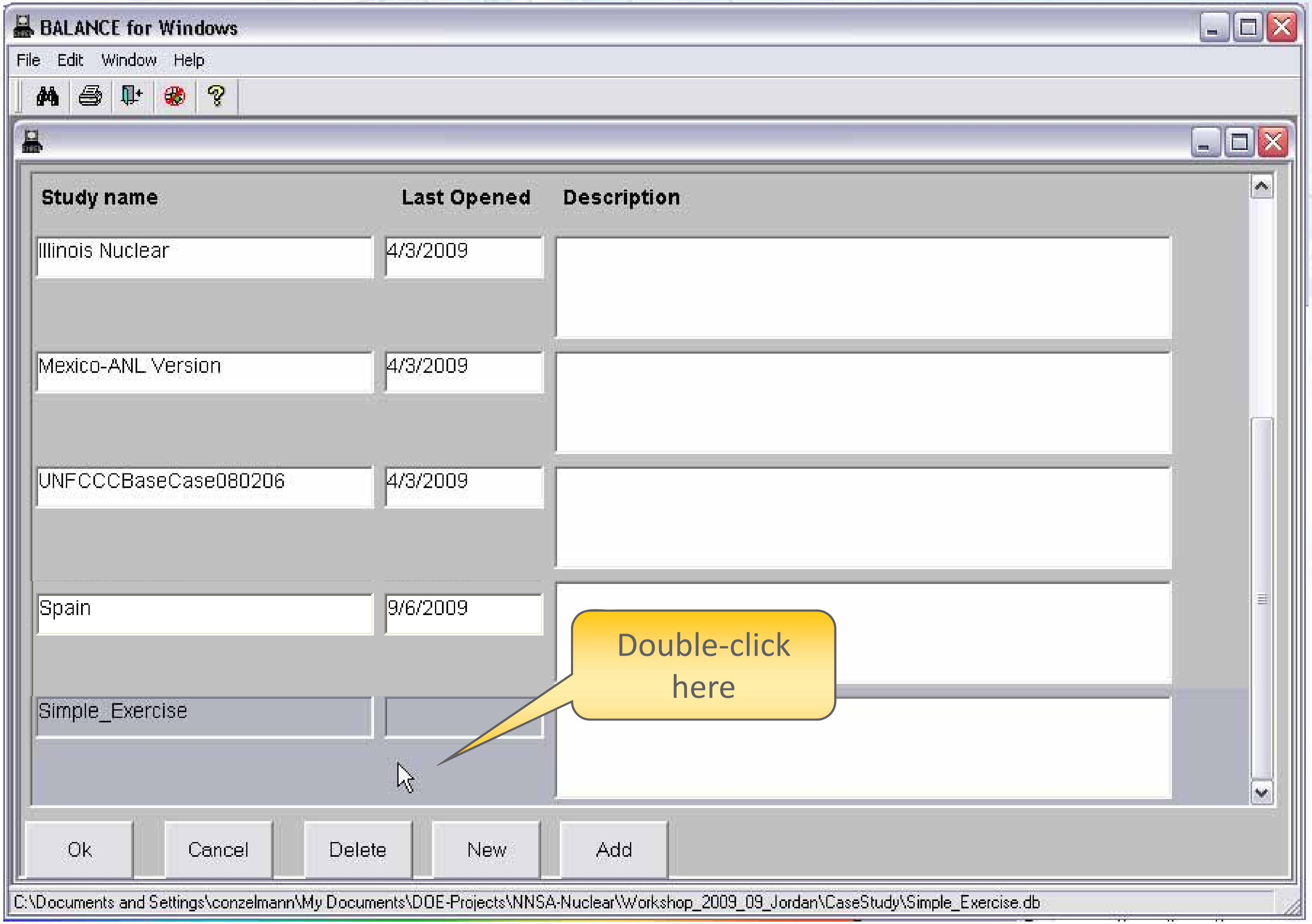
- Enter the input data
- Execution Step 2: Run the simulation
  - Click on "**Run BALANCE**"
  - Necessary when face is **RED (sad)**

- Review and interpret the results

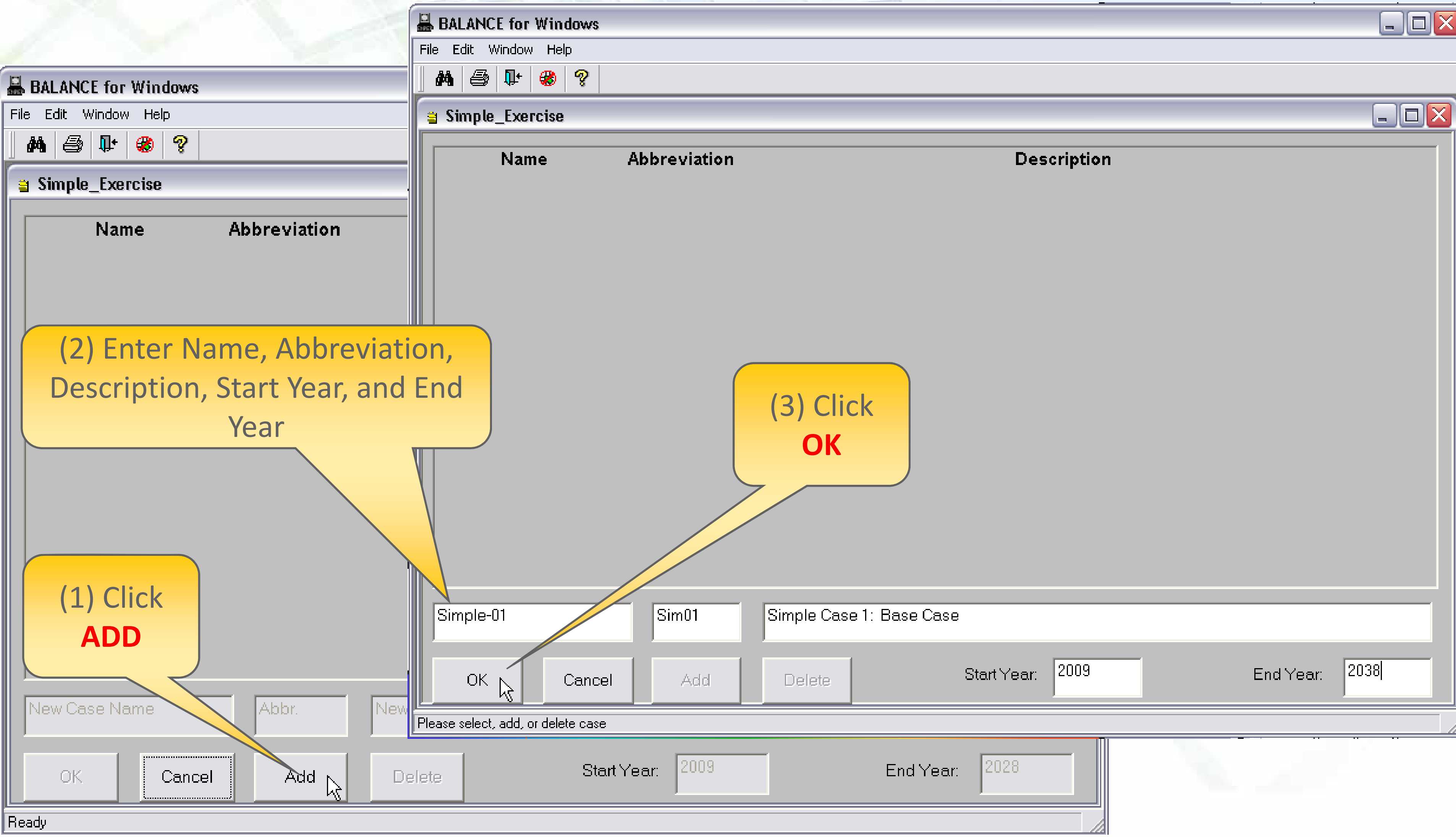
STEP 1: Create a New DATABASE



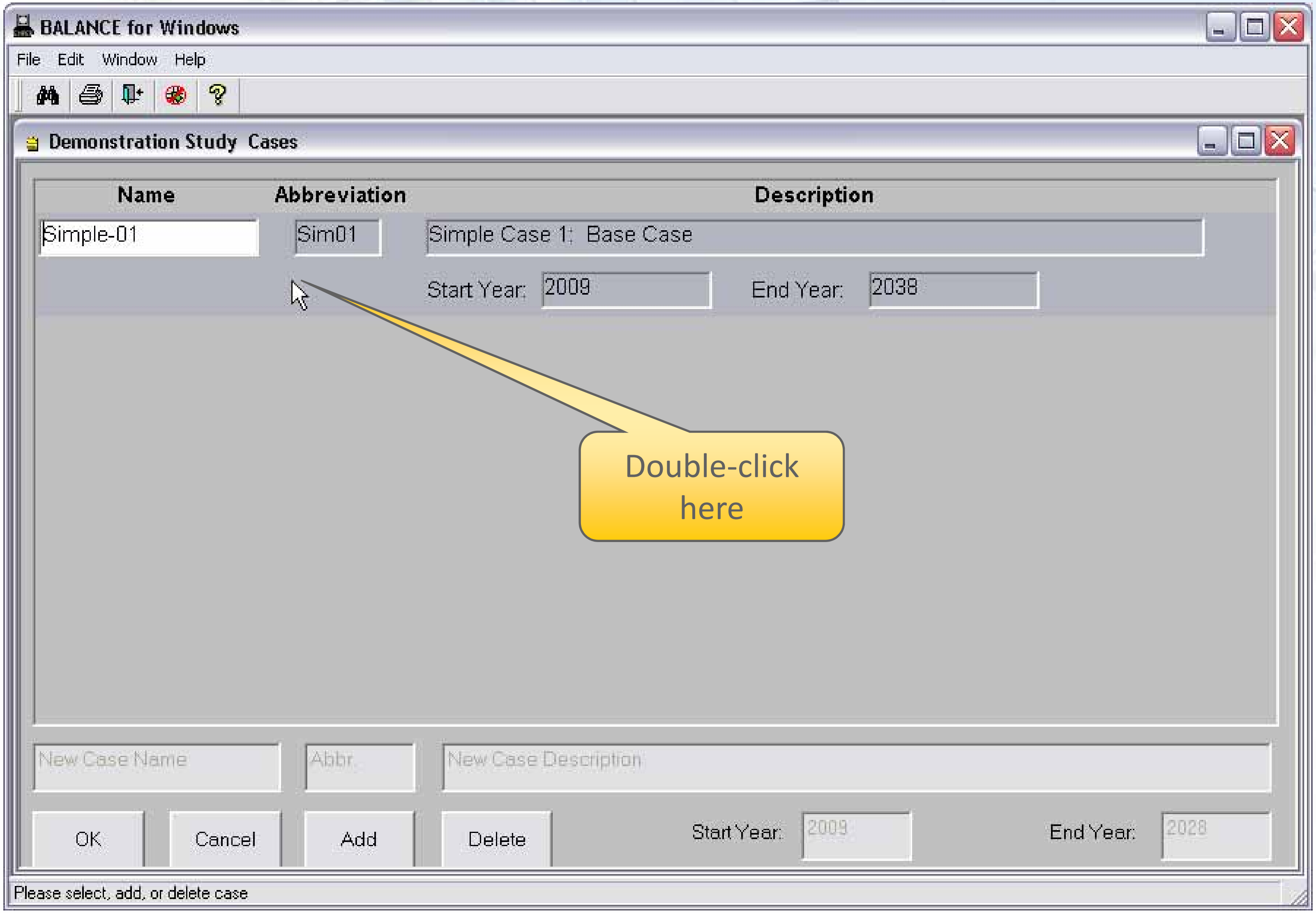
STEP 2: Open the New Database; Highlight the Name and Double-click



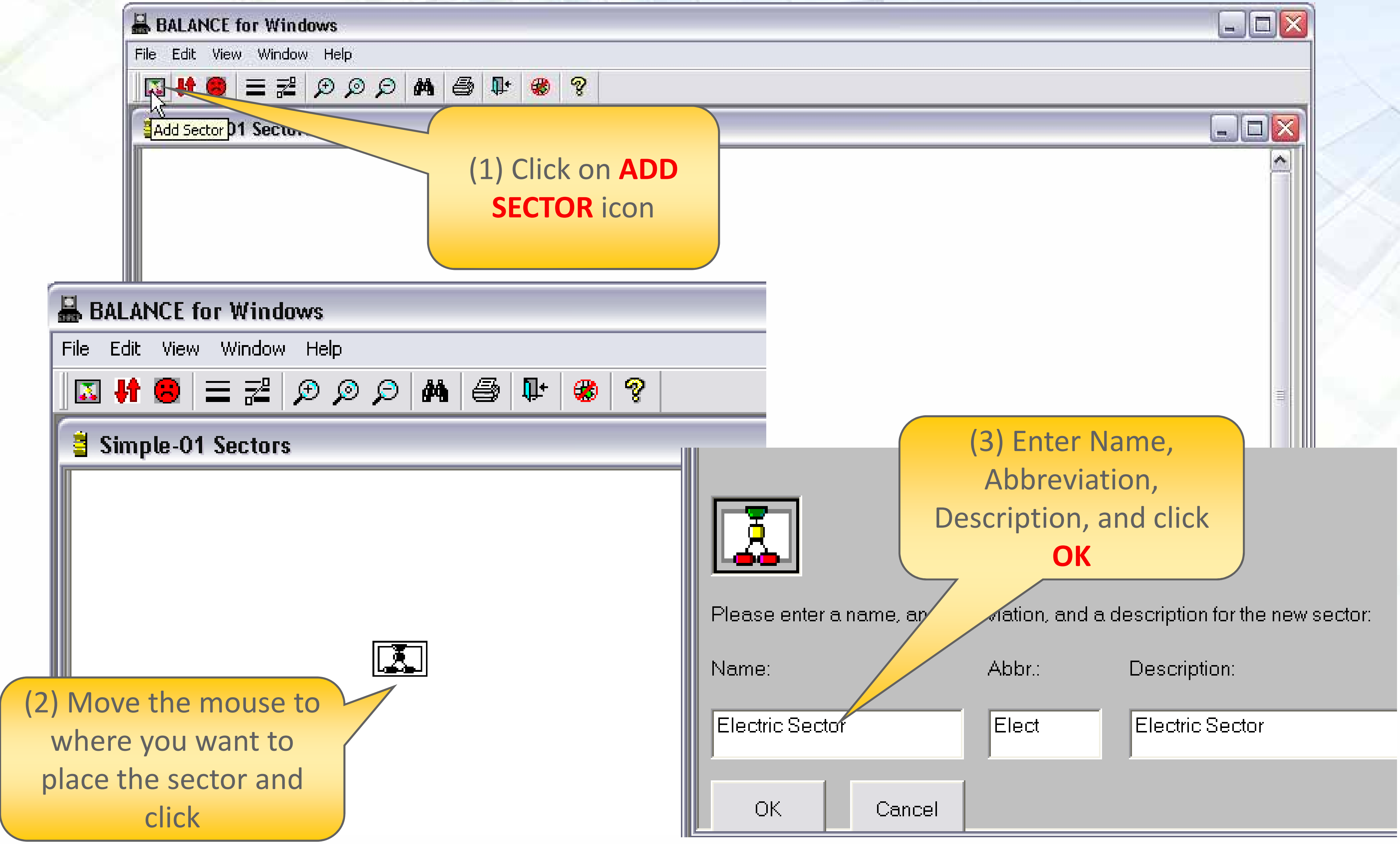
STEP 3: Create a New CASE



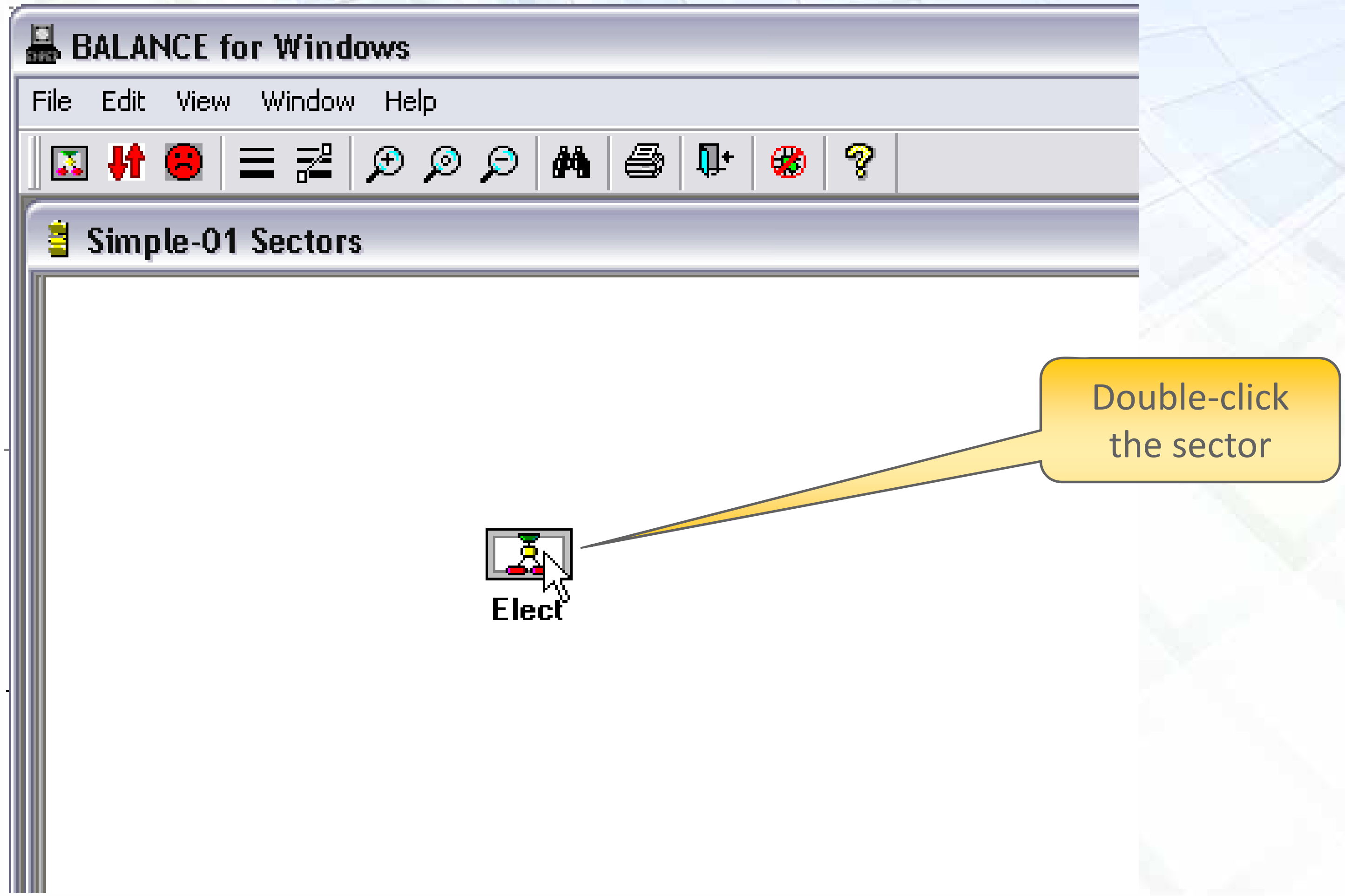
Step 4: Open the New Case ; Highlight the Name and Double-click



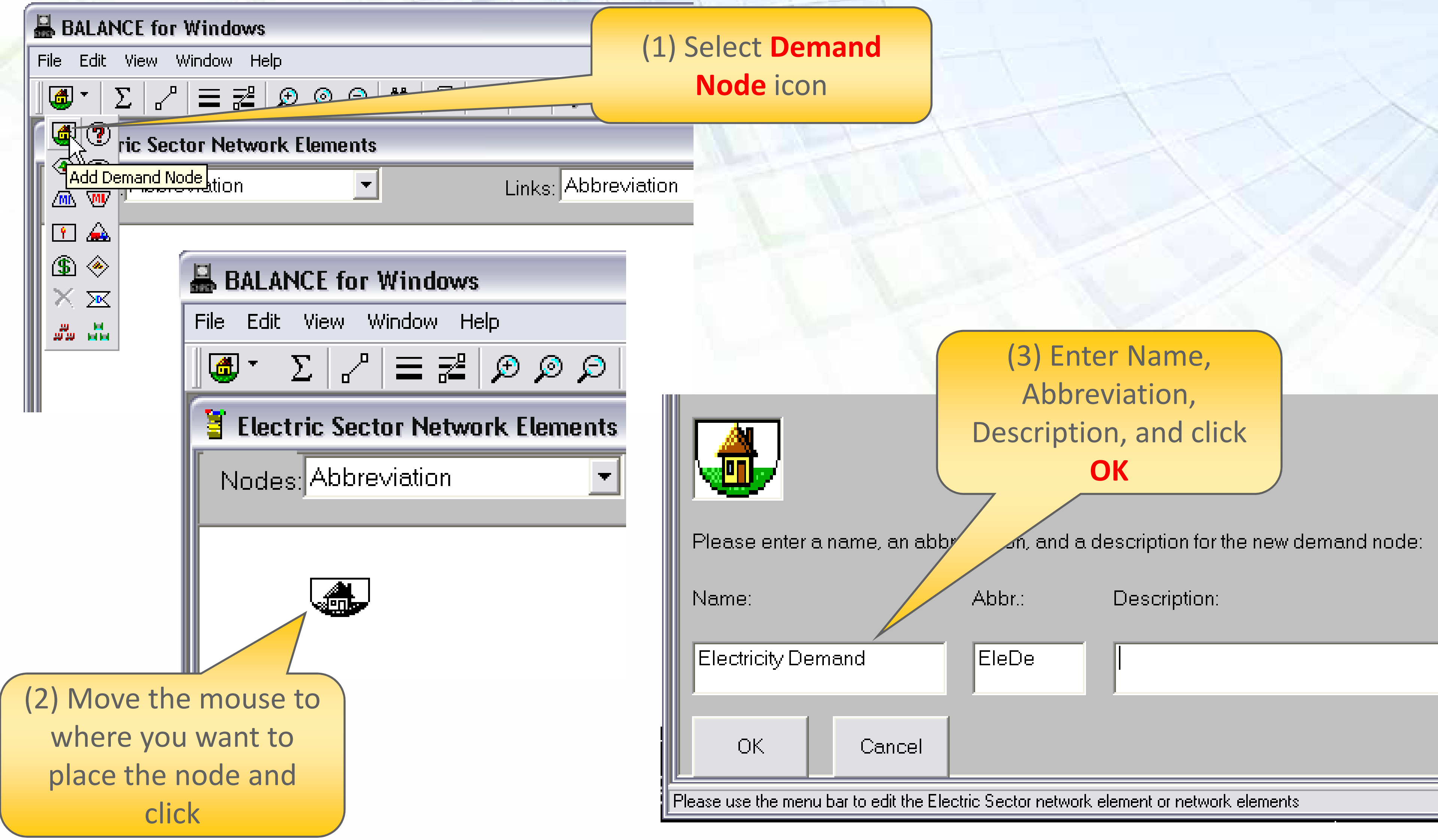
Step 5: Create New Sector and Name the Sector



Step 6: Enter the Sector by Double-clicking

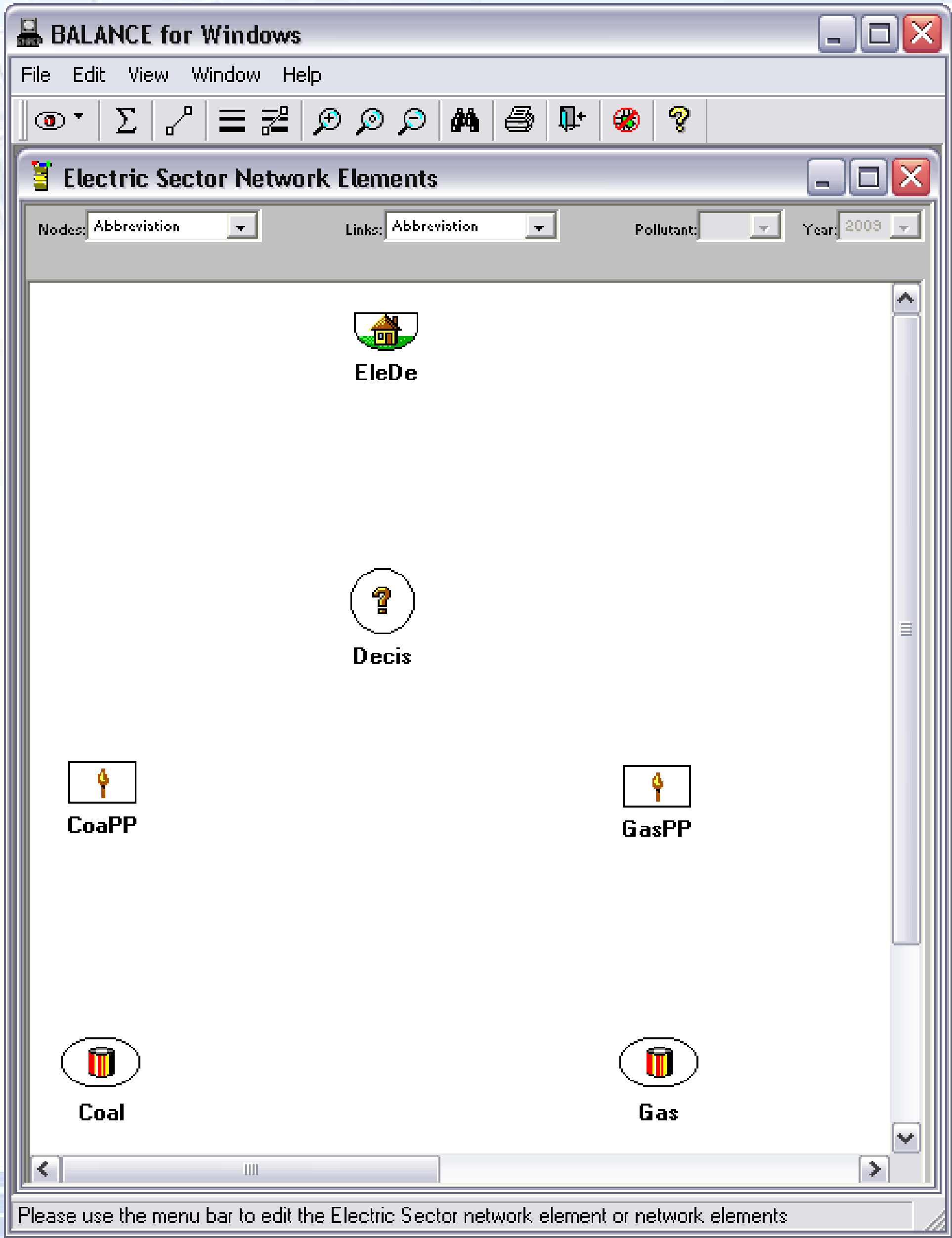


Step 7: Use the Node Pull-down Icon and Select the Node you Want to Include in the Sector



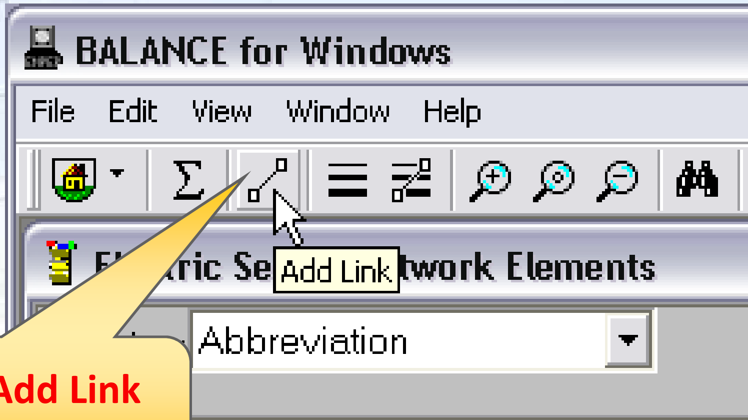
Step 8: Repeat Step 7 for all Nodes in the Network

- 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

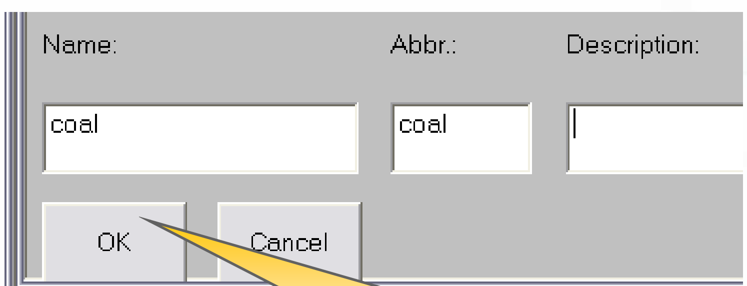
- Start at the bottom with the resources
- FROM – TO: Trace how energy flows from resource (bottom) to consumption (top)



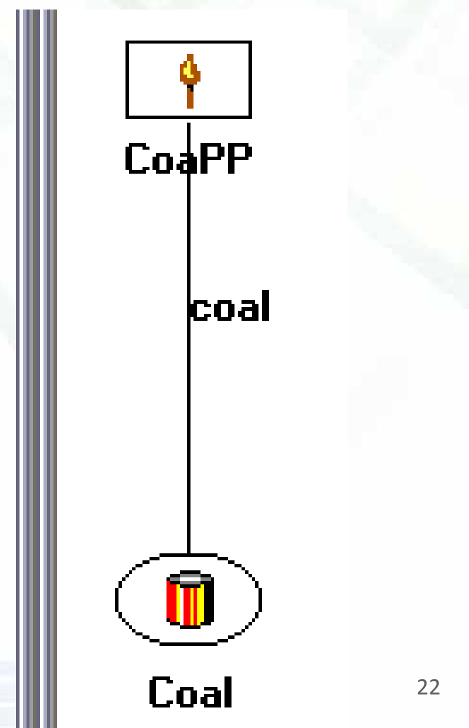
(1) Click on **Add Link** icon

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

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

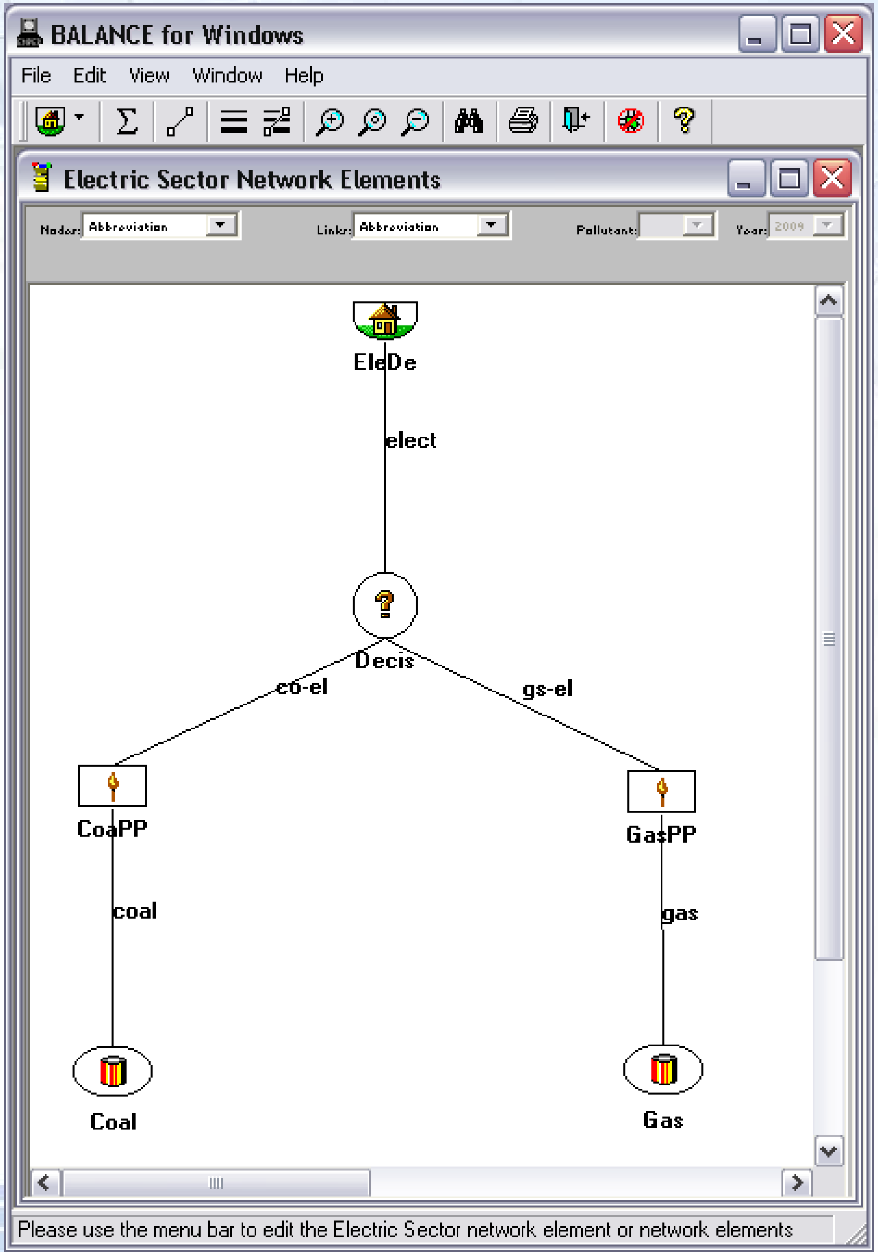


(4) Enter Name, Abbreviation, Description (optional), and click **OK**

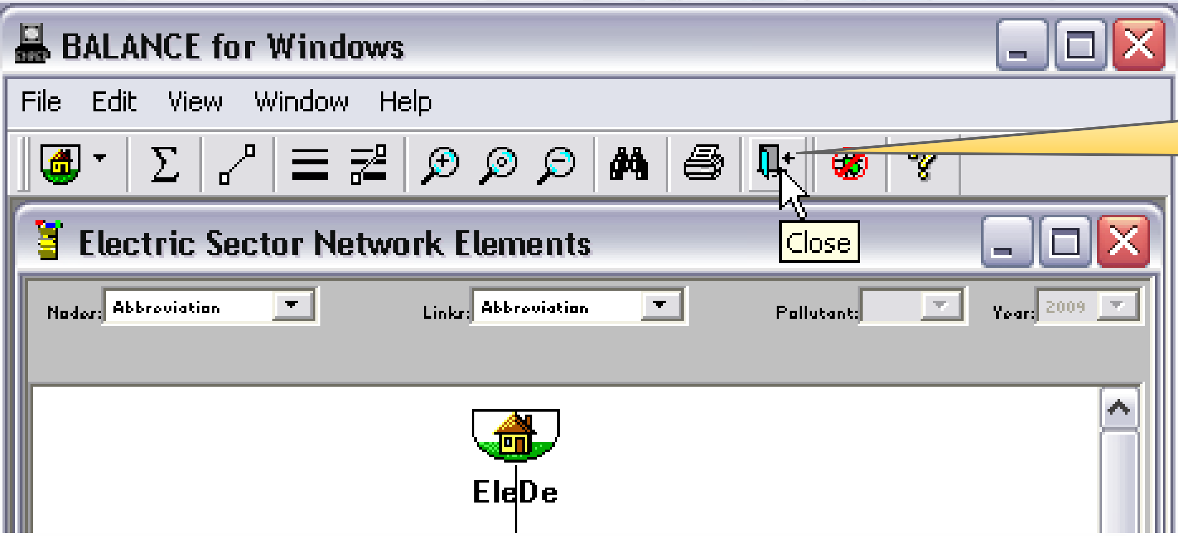


Step 10: Repeat Step 9 for all Links in the Network

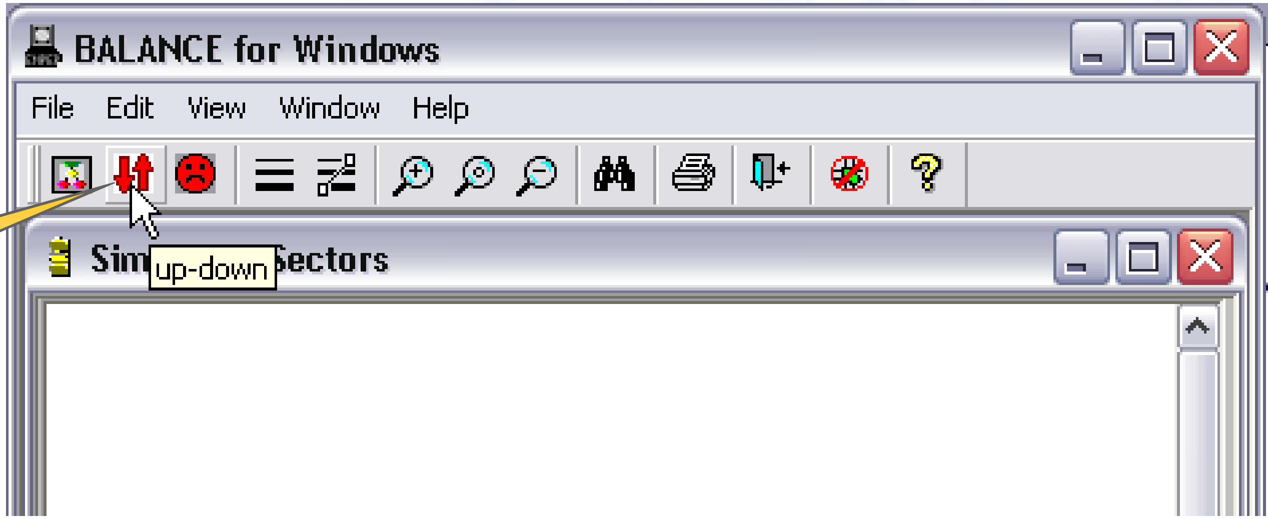
- Gas resource to gas power plant
  - Name: gas
  - Abbreviation: **gas**
- Coal power plant to decision node
  - Name: coal electricity
  - Abbreviation: **co-el**
- Gas power plant to decision node
  - Name: gas electricity
  - Abbreviation: **gs-el**
- Decision node to demand node
  - Name: electricity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



Step 11: Validate Integrity of Network Structure



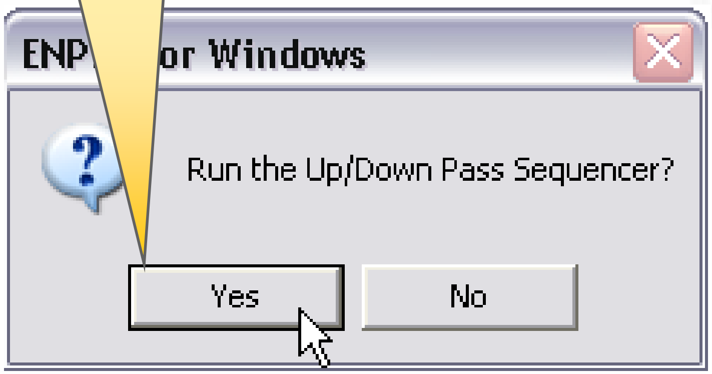
(1) Click on the **Close** icon to close the sector



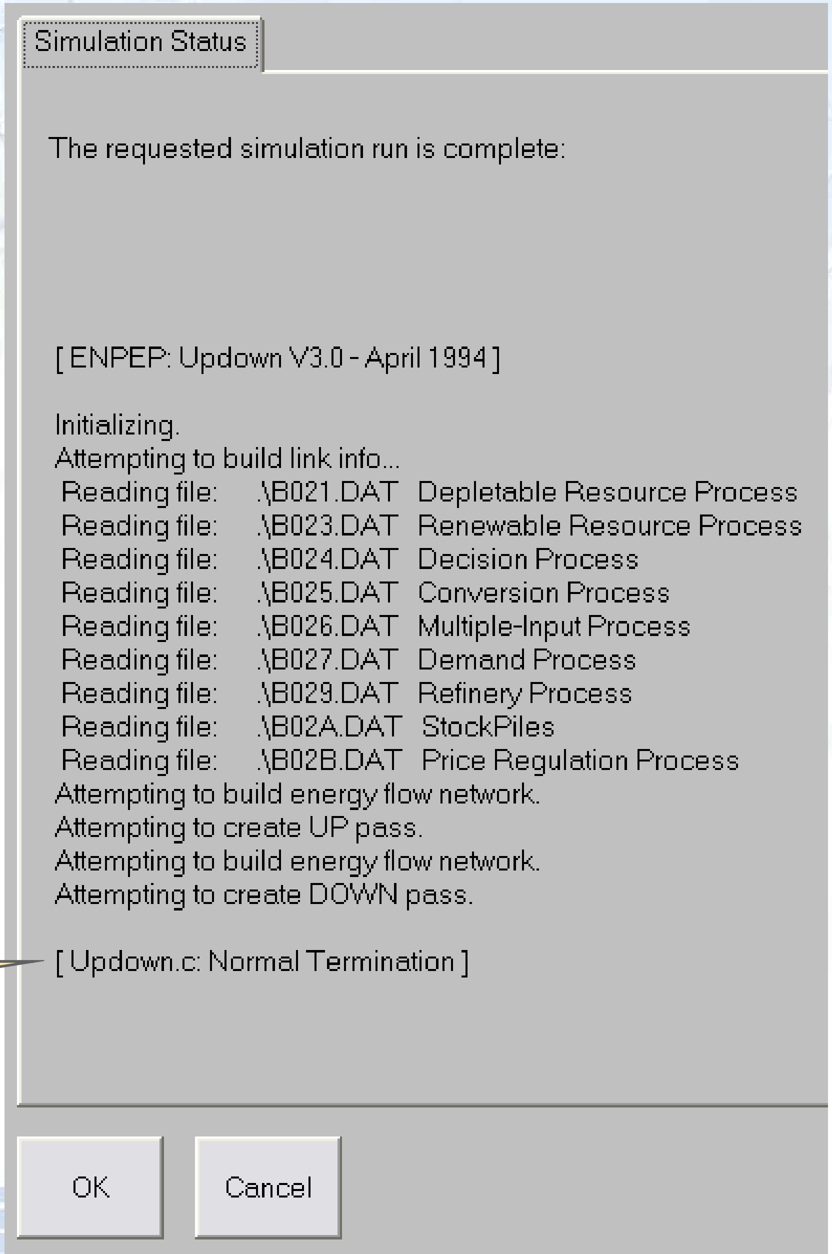
(2) Click on the **up-down** icon to run the validation

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): 6000

Year	Capacity (kboe)
2009	
2010	
2011	
2012	
2013	
2014	

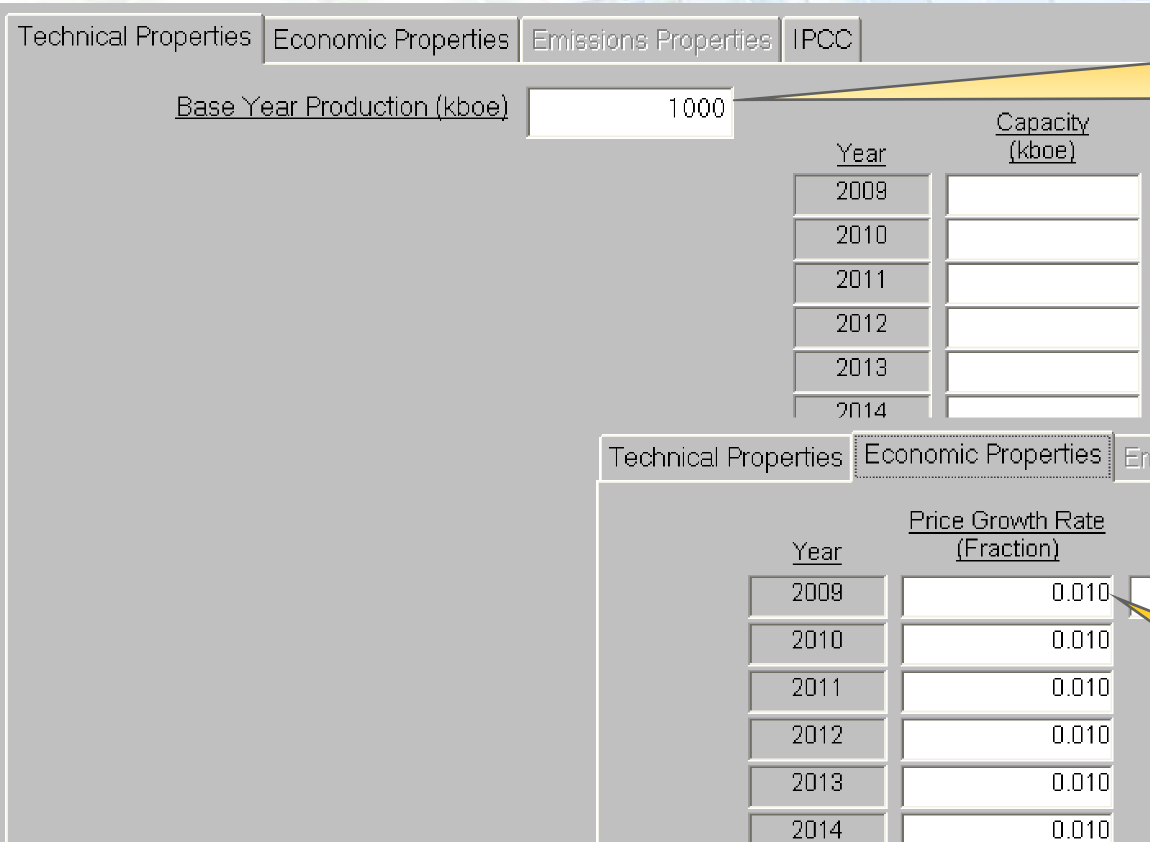
Coal consumption in 2009

Technical Properties | Economic Properties | Emissions Properties | IPCC

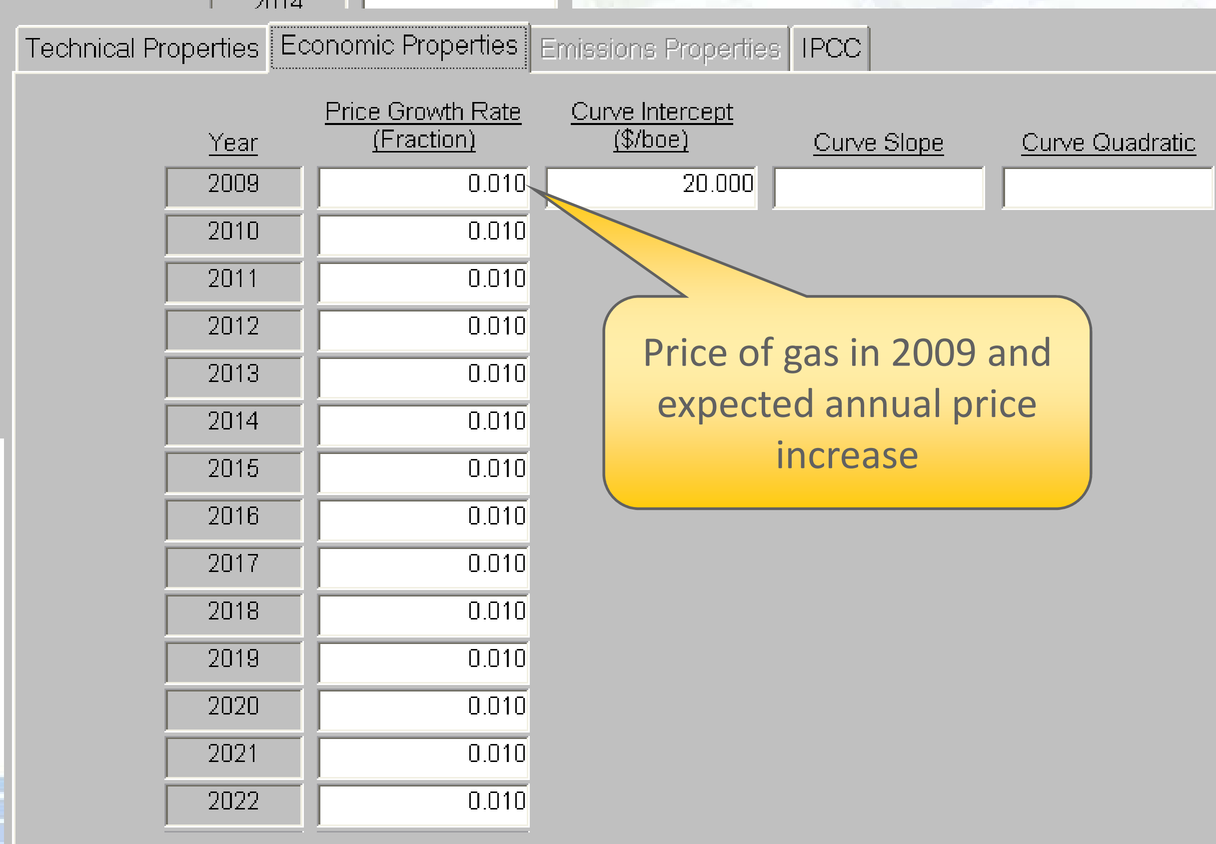
Year	Price Growth Rate (Fraction)	Curve Intercept ($/boe)	Curve Slope	Curve Quadratic
2009	0.015	9.000		
2010	0.015			
2011	0.015			
2012	0.015			
2013	0.015			
2014	0.015			
2015	0.015			
2016	0.015			
2017	0.015			
2018	0.015			
2019	0.015			
2020	0.015			
2021	0.015			
2022	0.015			

Price of coal in 2009 and expected annual price increase

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



Gas consumption in 2009



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

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	0.380
2010				
2011				
2012				

Technical Properties | Economic Properties | Emissions Properties

Year	Single Plant Capital Investment ($1000)	Operating and Maintenance Cost ($/boe)	Life Expectancy (Years)	Interest 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			**Sum:**	1
2010	co-el				
	gs-el				
2011	co-el				
	gs-el				

Technical Properties | Economic Properties

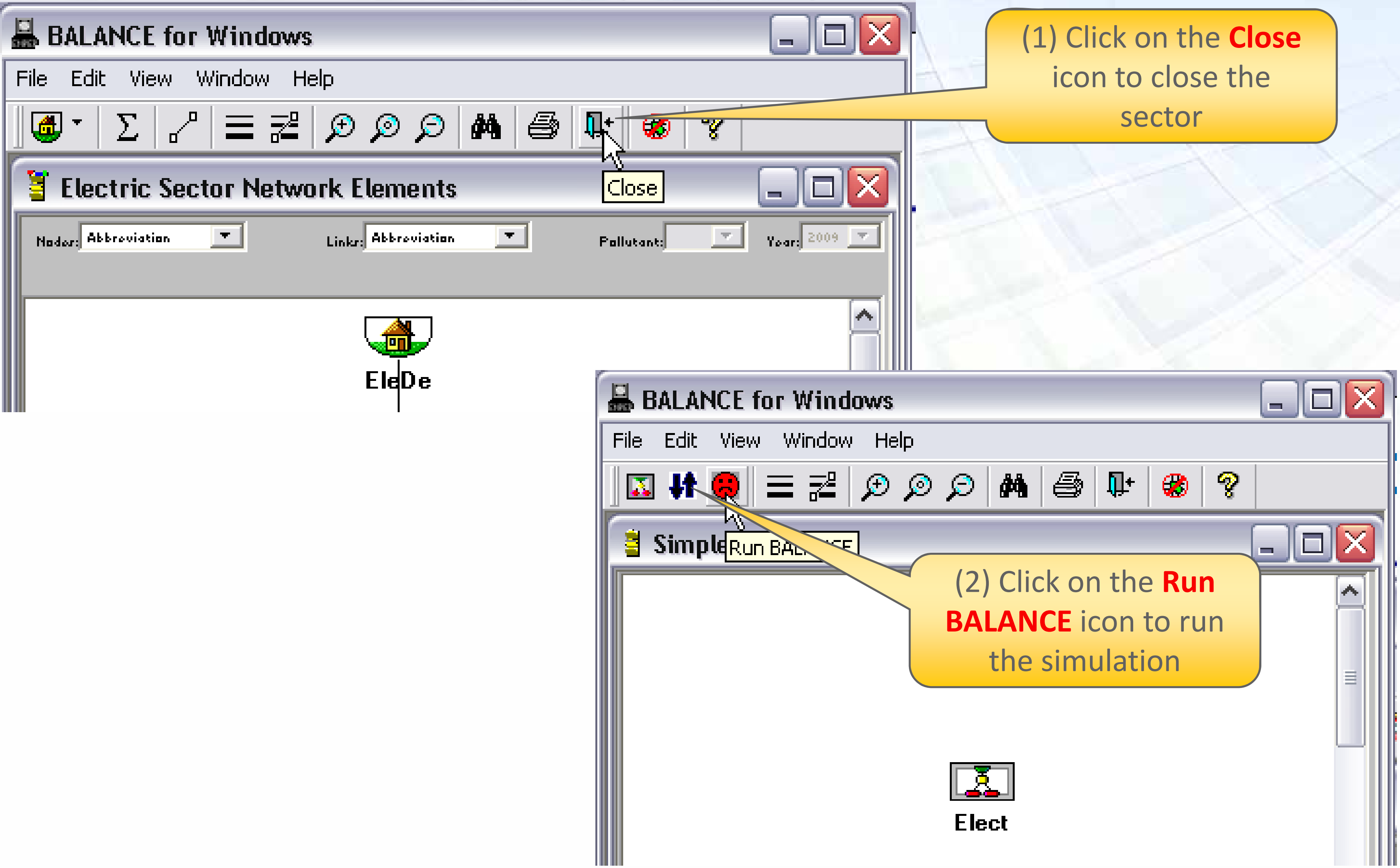
Year	Price Sensitivity	Lag Parameter (Fraction)	Electric Grid link	Stockpile	Run MSHARE
2009	3.000	0.100			☐

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		

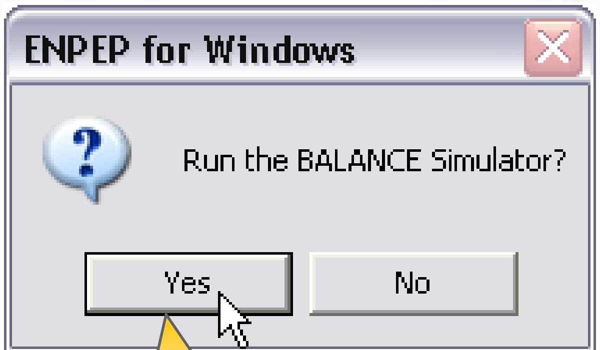
Step 16: Run ENPEP-BALANCE



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

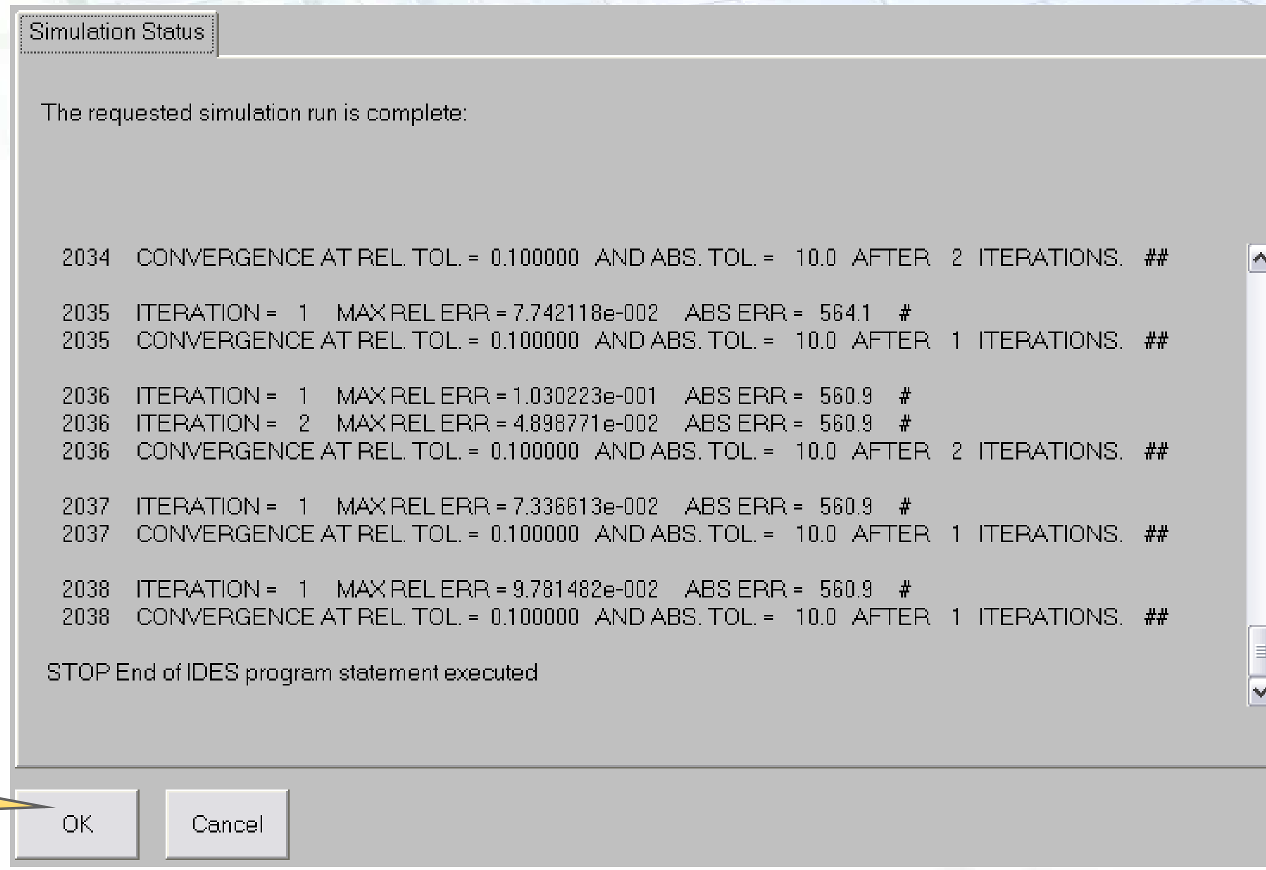
(2) Click on the **Run BALANCE** icon to run the simulation

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

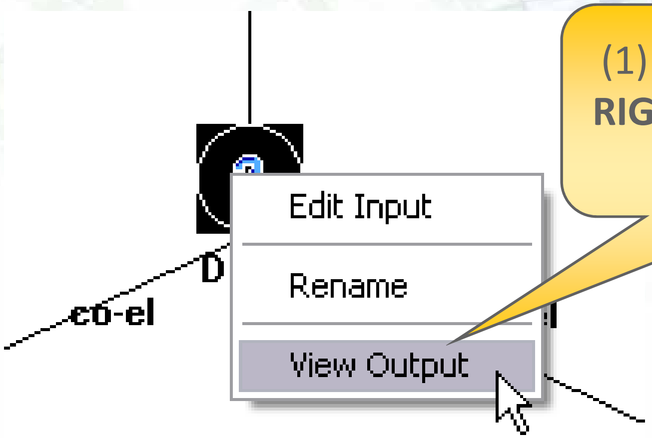


(1) Click **YES** to confirm

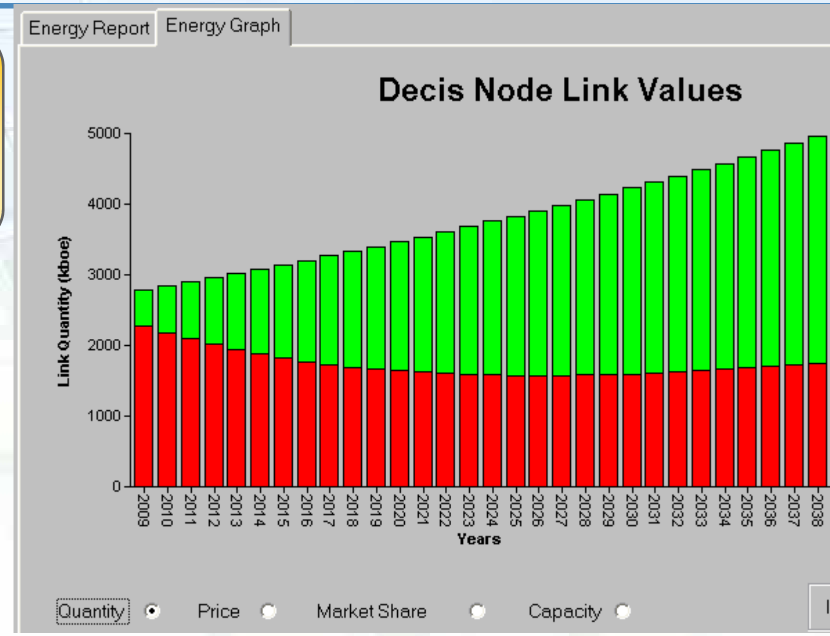
(2) If no warnings and error messages, click **OK**

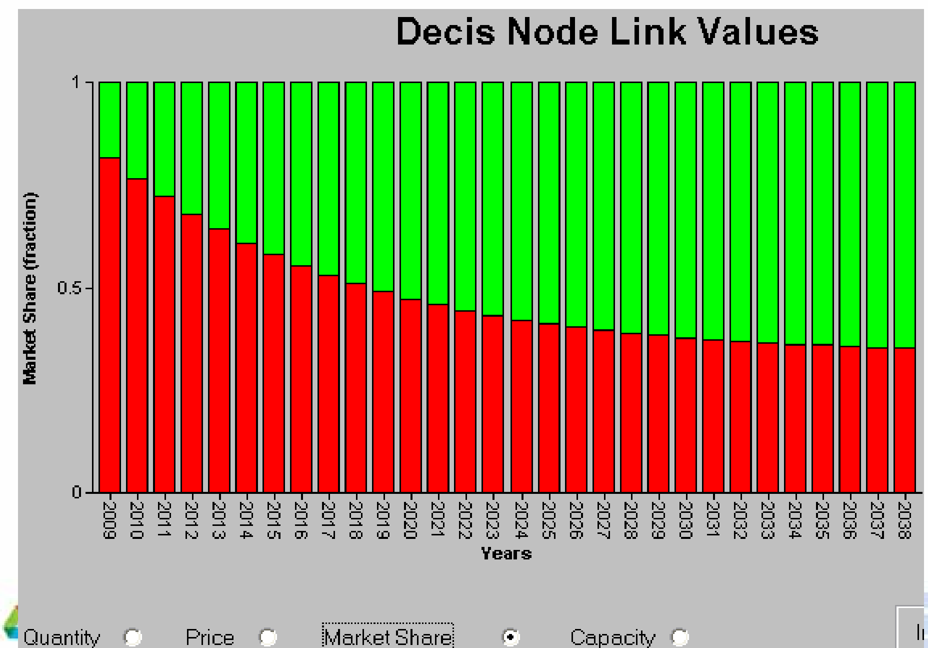


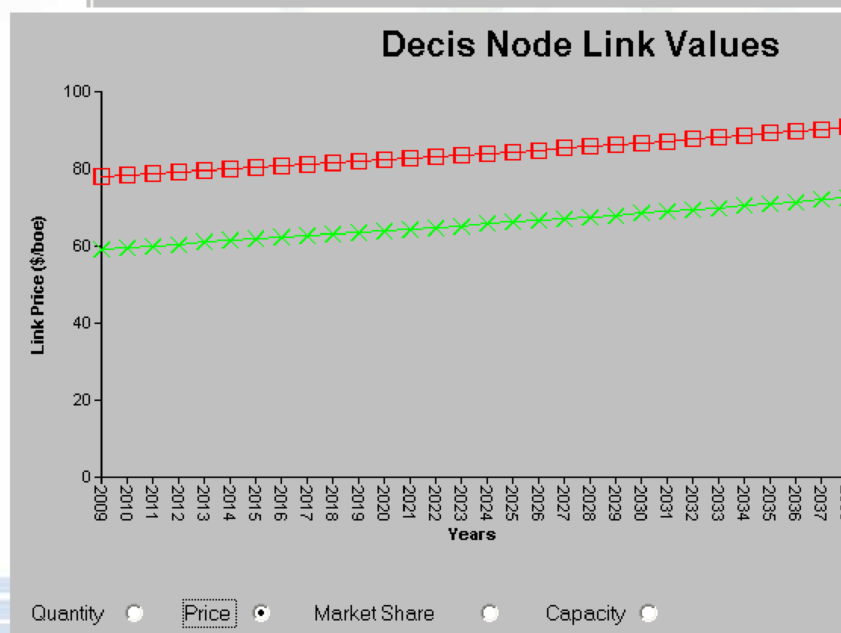
Step 17: Review Results at Decision/Allocation Node



(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	

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

Technical Properties | Economic Properties | Emissions Properties

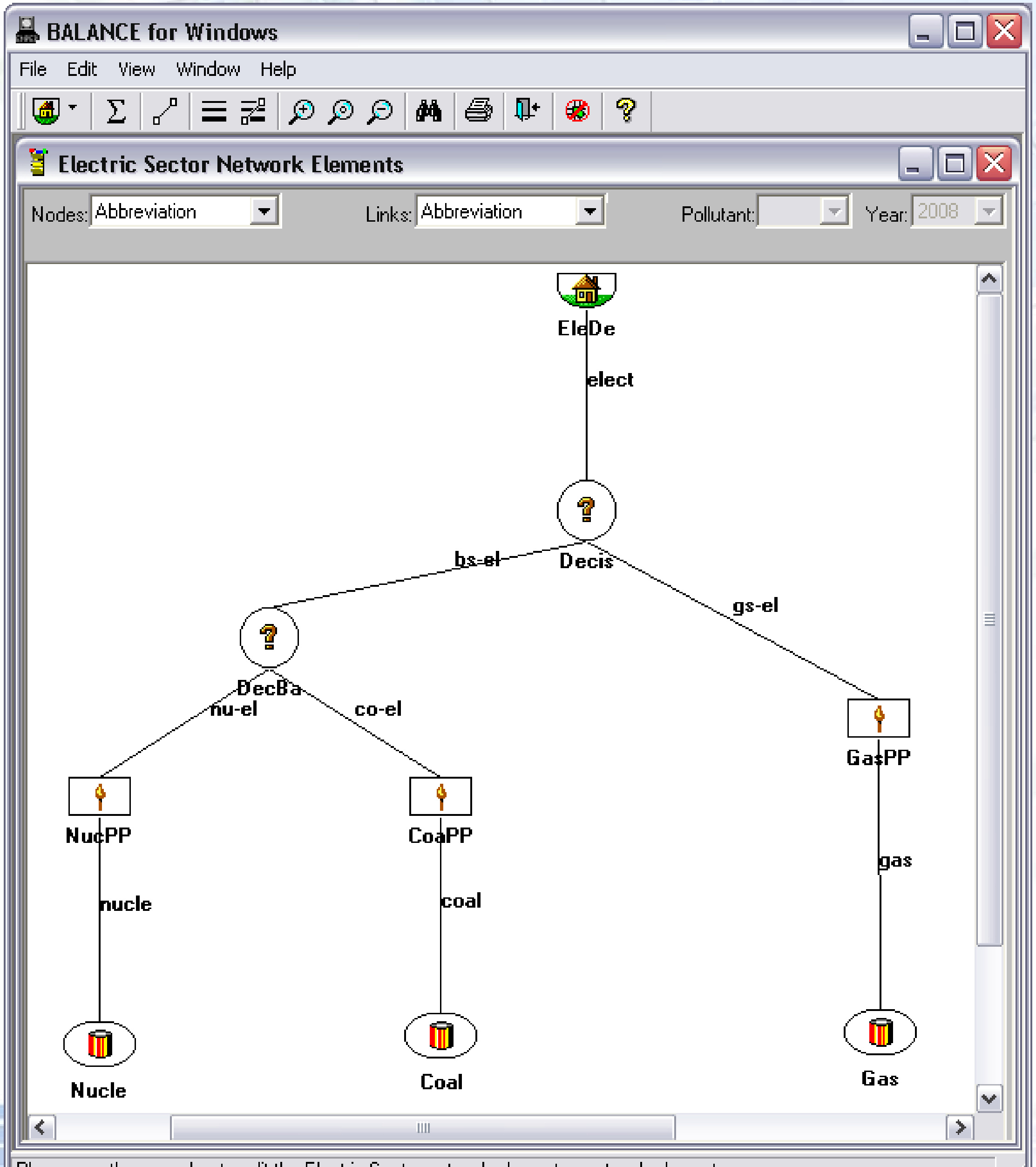
Year	Price Growth Rate	Curve Intercept ($/boe)
2009	0.010	20.000
2010	0.010	
2011	0.010	
2012	0.010	
2013	0.010	
2014	0.010	
2015	0.010	
2016	0.040	
2017	0.040	
2018	0.040	
2019	0.040	
2020	0.040	
2021	0.040	
2022	0.040	

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

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): 0

Year	Capacity (kboe)
2009	
2010	
2011	
2012	
2013	
2014	

Technical Properties | Economic Properties | Emissions Properties | IPCC

Year	Price Growth Rate	Curve Intercept ($/boe)	Curve Slope	Curve Quadratic
2009	0.010	2.500		
2010	0.010			
2011	0.010			
2012	0.010			
2013	0.010			
2014	0.010			
2015	0.010			
2016	0.010			
2017	0.010			

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

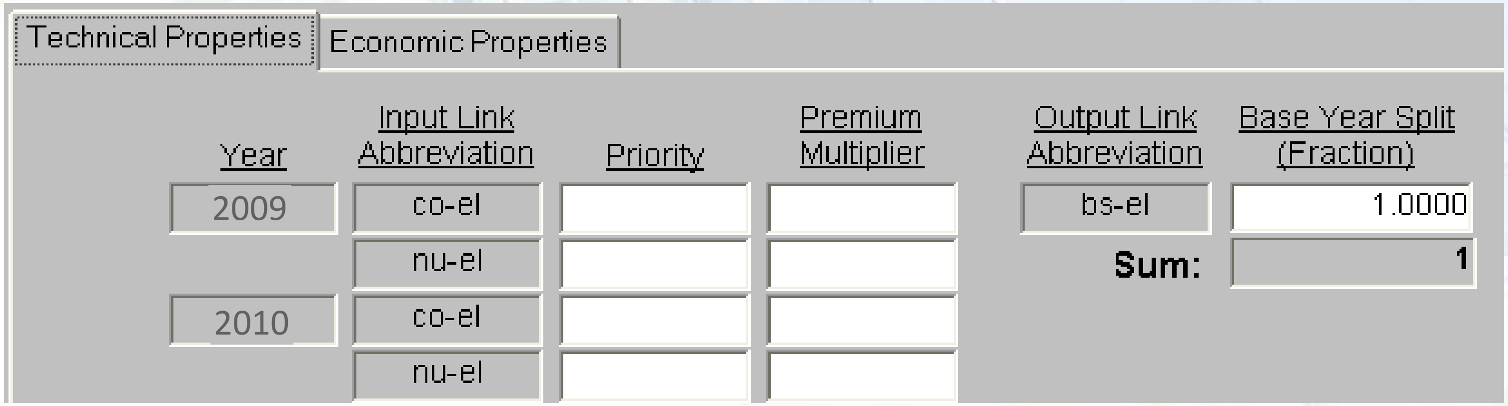
Technical Properties | Economic Properties | Emissions Properties

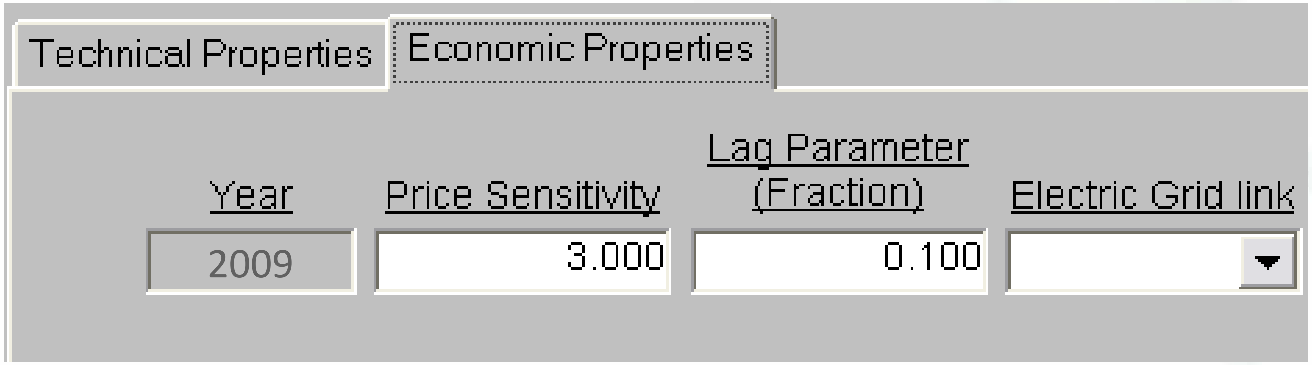
Year	Single Plant Output Capacity (kboe)	All Plants Output Capacity (kboe)	Typical Capacity Factor (Fraction)	Output/Input Ratio (Fraction)
2009	7,604.000		0.900	0.330
2010				
2011				
2012				
2013				
2014				
2015				
2016				
2017				
2018				
2019		999,999.000		
2020				
2021				

Technical Properties | Economic Properties | Emissions Properties

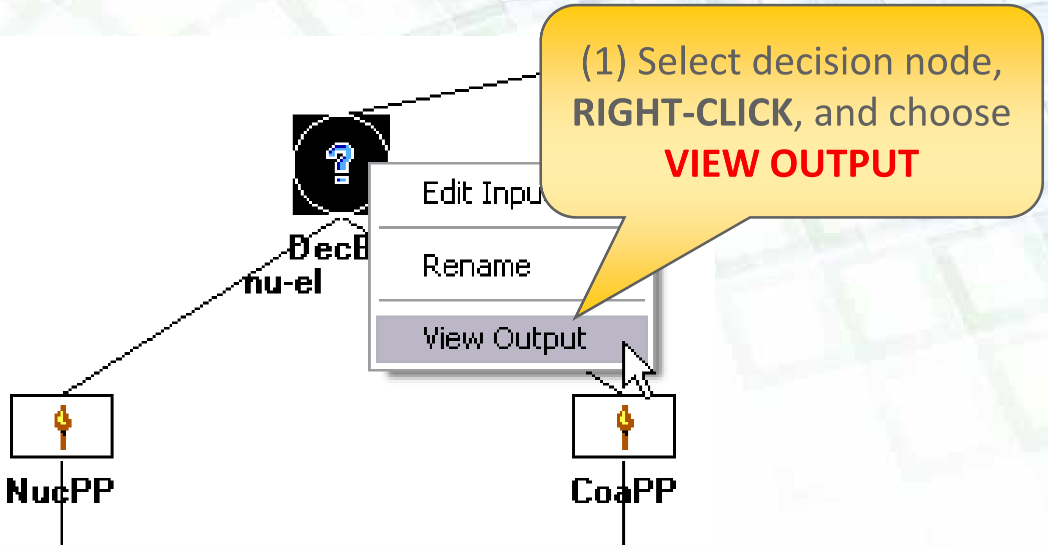
Year	Single Plant Capital Investment ($1000)	Operating and Maintenance Cost ($/boe)	Life Expectancy (Years)	Interest Rate (Fraction)
2009	3,500,000.000	0.800	40.00	0.100
2010				
2011				

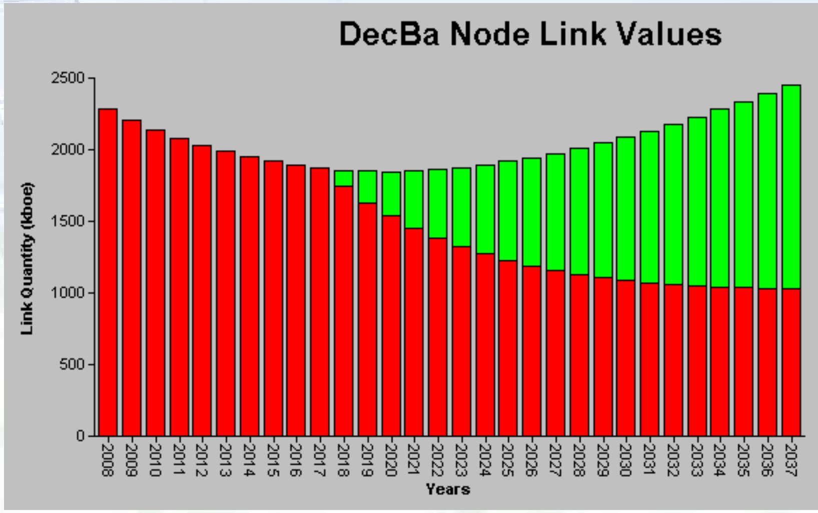
Step 3: Enter Input Data – Decision/Allocation Node

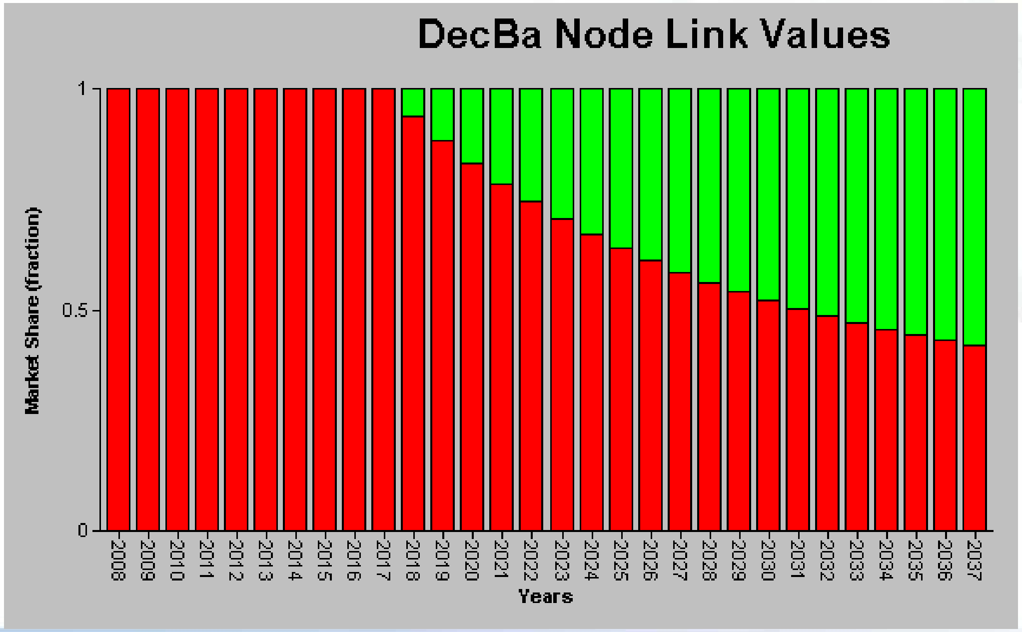




Step 4: Review Results at Decision/Allocation Node







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	Scale Value (%)	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	Scale Value (%)	Emissions Tax ($/tonne)
2009	CH4				
	CO2	50.000	Carbon		30.00

Gas plant; emission factor and carbon price