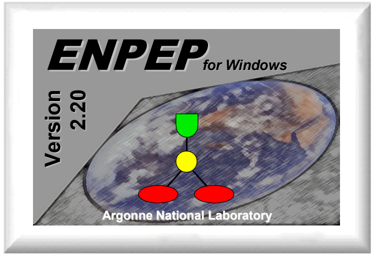
# ENPEP-BALANCE Methodology and Data Requirements

**ENPEP-BALANCE Training Course**
Singapore
December 5-9, 2011

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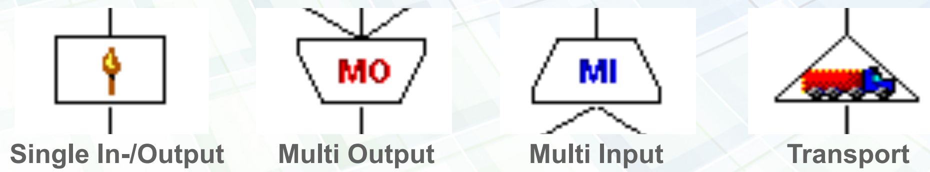
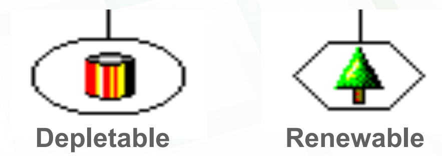
# *Node Types Available in BALANCE - Each Node is Essentially a Sub-Module with Specific Algorithms*

- Demand

- Conversion Processes




- Resource Processes




- Economic Processes


- Electricity Dispatch and Thermal and Hydro Units

# Objective of this Presentation: Detailed Node-by-Node Review

- The objective of the lecture is to review the methodology and data requirements for all BALANCE nodes (demand node, conversion nodes, resource nodes, …)
- For all nodes, the following will be discussed:
  - Input data
  - Methodology and equation(s)
  - Modeling guidelines
- The lecture will concentrate on non-electric nodes; the electric nodes will be covered in a separate lecture
- Also, the multiple-output node and the stockpile node will be covered during a later presentation

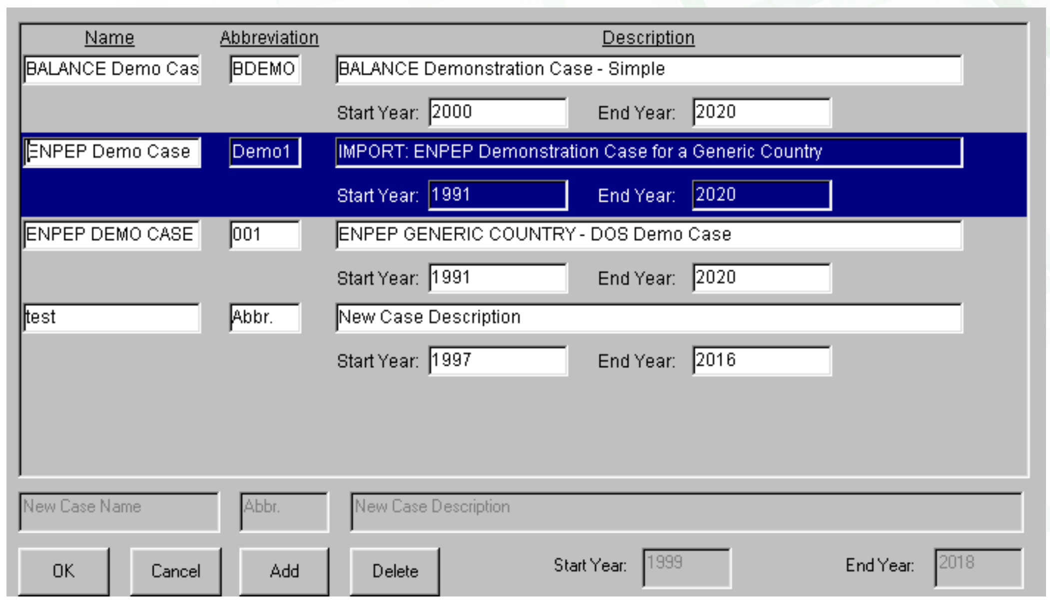
# BALANCE Data Requirements

- Case-level information
  - Study period
  - Convergence information
  - Report types generated
  - Input/output units for electric and non-electric processes

- Process-level information
  - Resources (depletable and renewable)
  - Conversion processes (single input, multiple input, multiple output)
    - Multiple output node covered later
  - Decision/allocation nodes
  - Stockpile nodes (covered in separate presentation)
  - Pricing nodes
  - Electric generating unit data
  - Capacitated links
  - Demand nodes

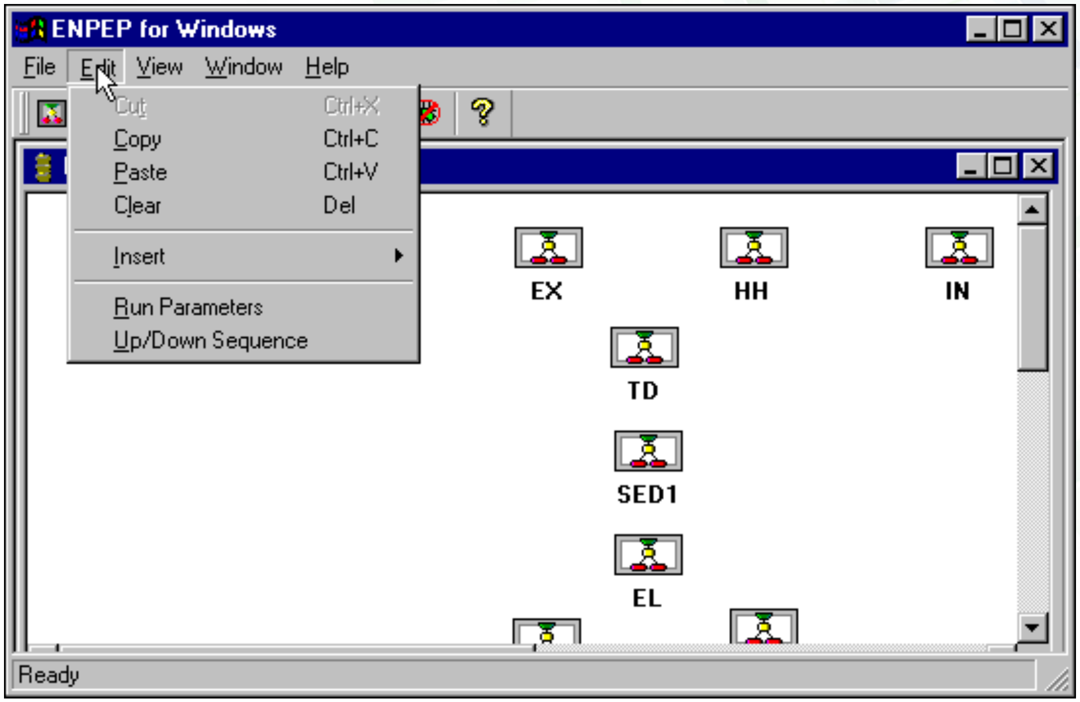
# Case Level Input Data

- Study period
  - Defined when creating a new case
  - Can be modified later
- When modifying study period, all input data need to be verified
  - Relatively few changes are needed when modifying the end year
  - More substantial changes are required when modifying the base year (CAREFUL!!)



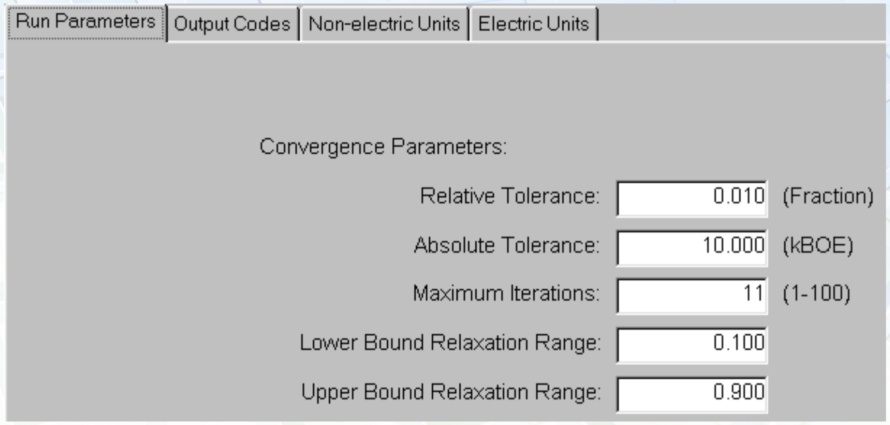
# Case Level Input Data

- The remainder of the case-level information can be accessed at the sector-level through the menu under ***Edit-Run Parameters***
  - Convergence information
  - Report types generated
  - Input/output units for electric and non-electric processes



# Case-Level Input Data - Run Parameters

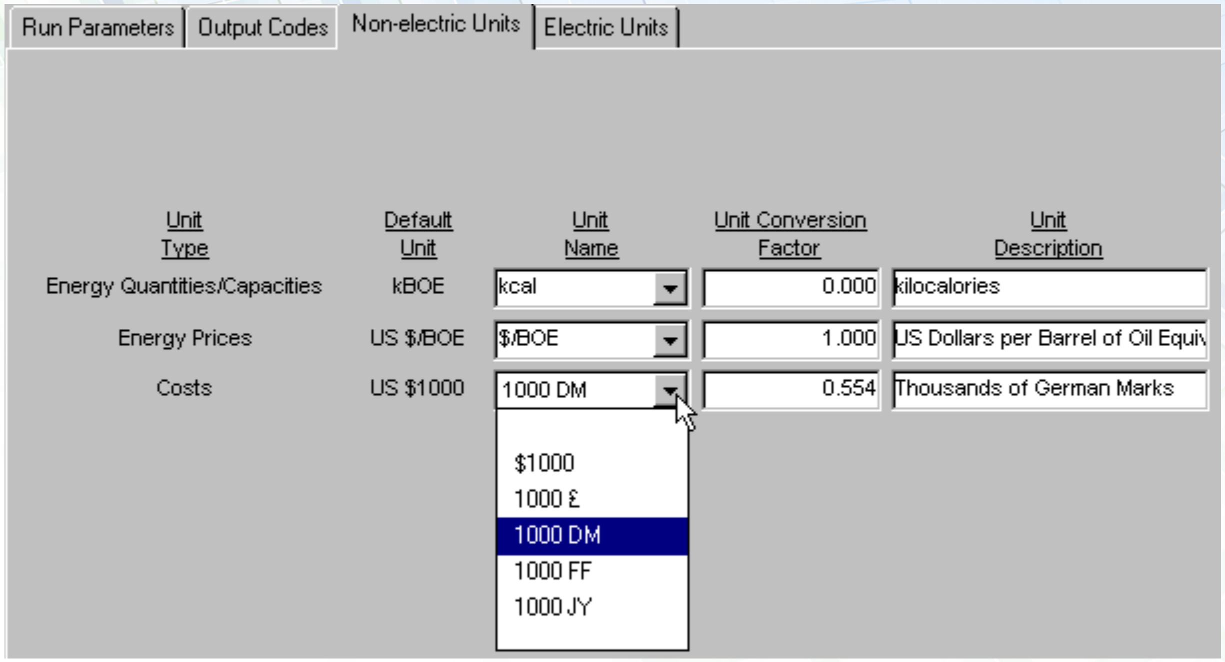
- Convergence ***Tolerance***
  - Relative (fraction)
  - Absolute (kBOE)
  - Represents the allowable convergence tolerance
  - If the convergence error is less than this value, the system is converged for that particular year;  the model advances to the next year and resumes the iteration




- ***Maximum Iterations*** represents the maximum number of iterations allowed for model convergence in a single year;  if the system is not converged in a particular year after performing the maximum iterations, the model terminates
- ***Lower and Upper Bound Relaxation Range*** indicates the fraction of the interval between successive iterations that will be used to estimate the equilibrium quantity on the next iteration
  - default values are 0.1 for lower and 0.9 for upper bound
- If the model does not converge, you may want to try to (1) increase the number of maximum iterations, (2) decrease the lower bound to 0.001, or (3) increase the upper bound to 0.999

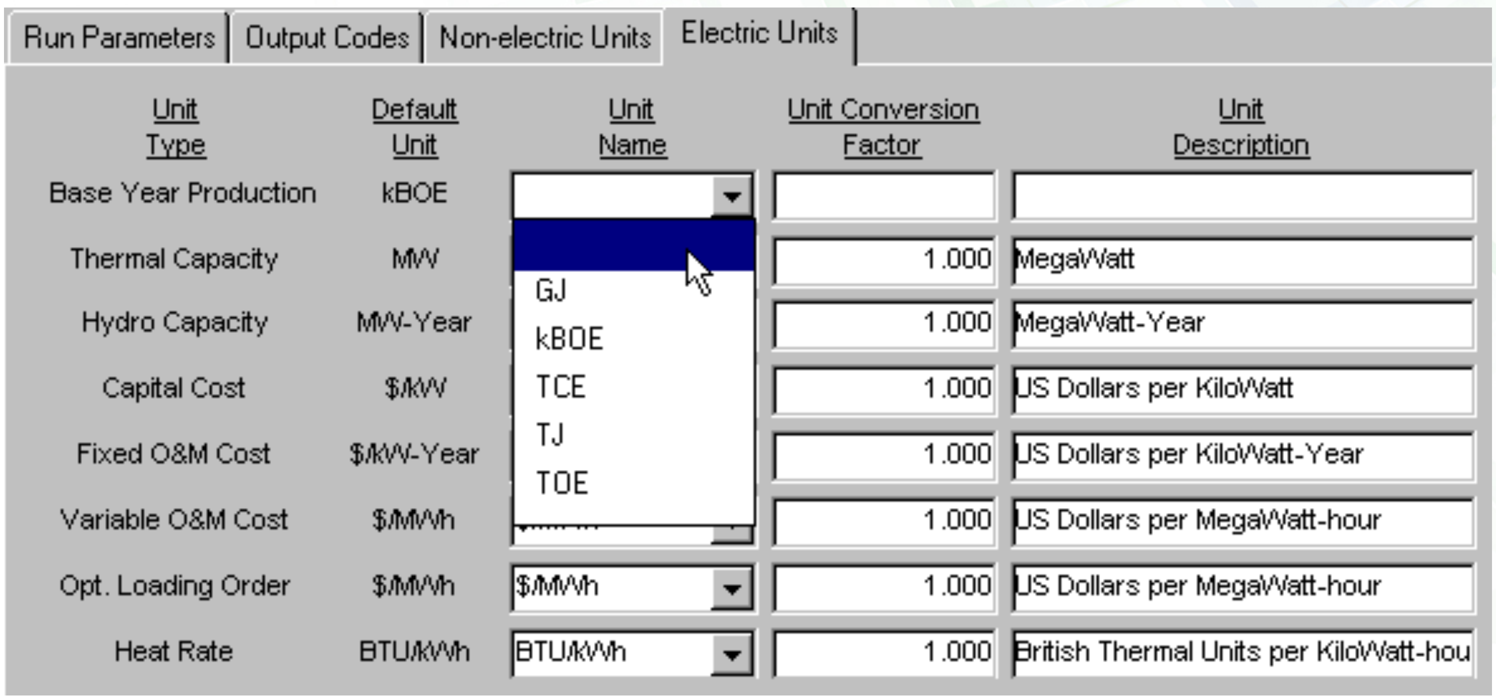
# Case-Level Input Data - Non-Electric Units

- Allows the user to choose the unit of choice for input data and model output
- The ***Default Unit*** is the unit that the model uses internally
- The pull-down menu under ***Unit Name*** provides the user with a choice of alternative units; the user can add to the list (select blank field) or delete items from the list
- The ***Unit Conversion Factor*** is a factor that the model uses internally to convert the user-selected unit back to the default unit
- Please select the unit at the beginning of the study



# Case-Level Input Data - Electric Units

- Similar to non-electric units
- When the user selects an alternative unit, all unit displays on all input screens will be modified
- All model outputs will be reported in the user-selected unit (however, internally the model uses the default unit during the computations)



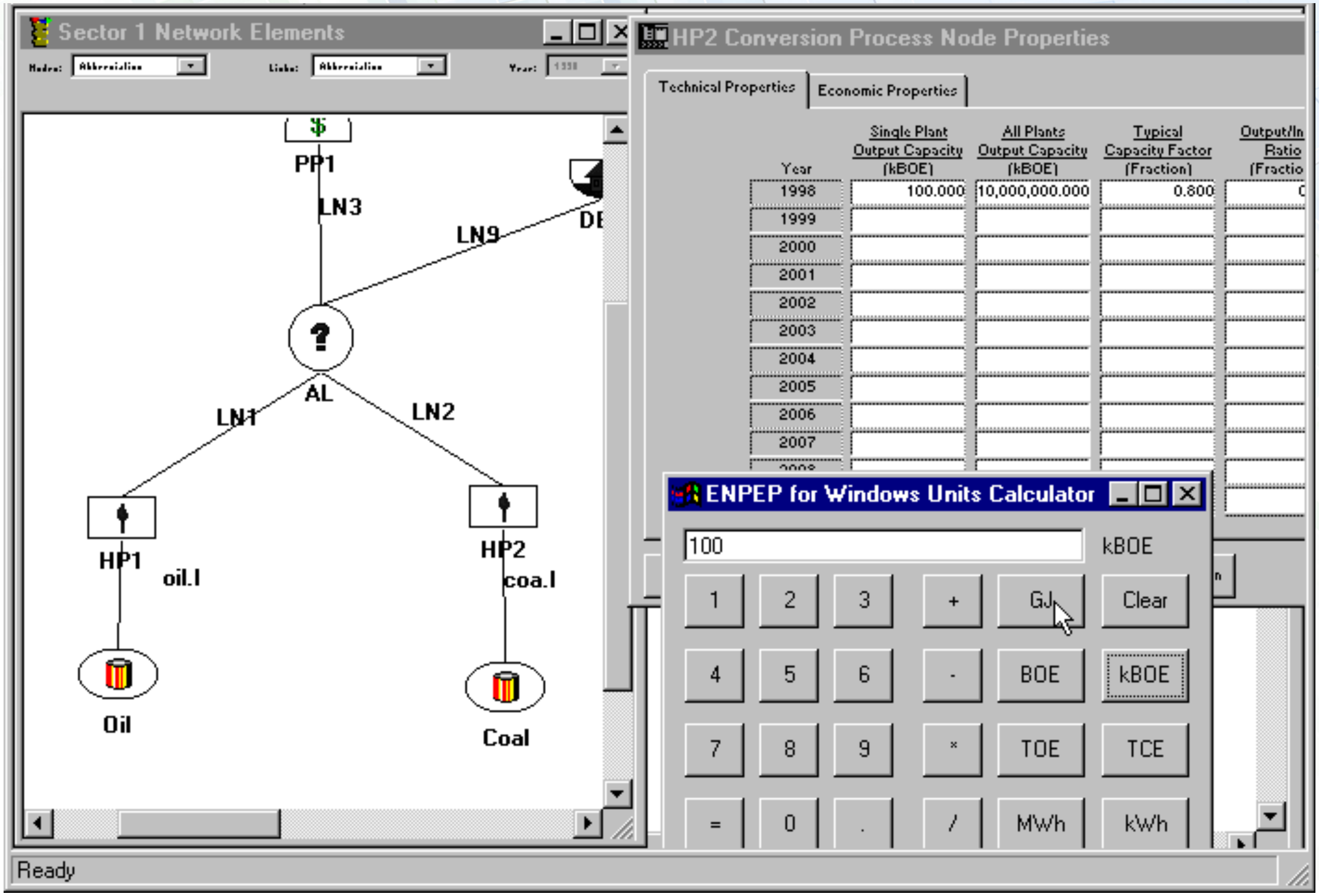
# *Case-Level Input Data - Units*

- Select the UNITS for energy flows, prices, costs, and emissions EARLY and try not to change them during the course
- If you enter a USER-DEFINED UNIT, make sure you use the CORRECT UNIT CONVERSION FACTOR
- Value should be entered as default unit per user unit, double-check the value before entering a lot of data (*if you enter the wrong value and have to correct it later, you will need to re-enter some input data*)
- Example: Default unit: US$1000
  Unit name: DM1000
  Unit conversion factor: 0.554
- Example: Default unit is kBOE
  Unit name is ktoe
  Unit conversion factor: 7.3

$$0.554 \ x \left( \frac{US\$1000}{DM1000} \right)$$

$$7.3 \ x \left( \frac{kBOE}{ktoe} \right)$$

# The ENPEP Units Calculator May be Used in Converting Units from BOE/kBOE to Other Units



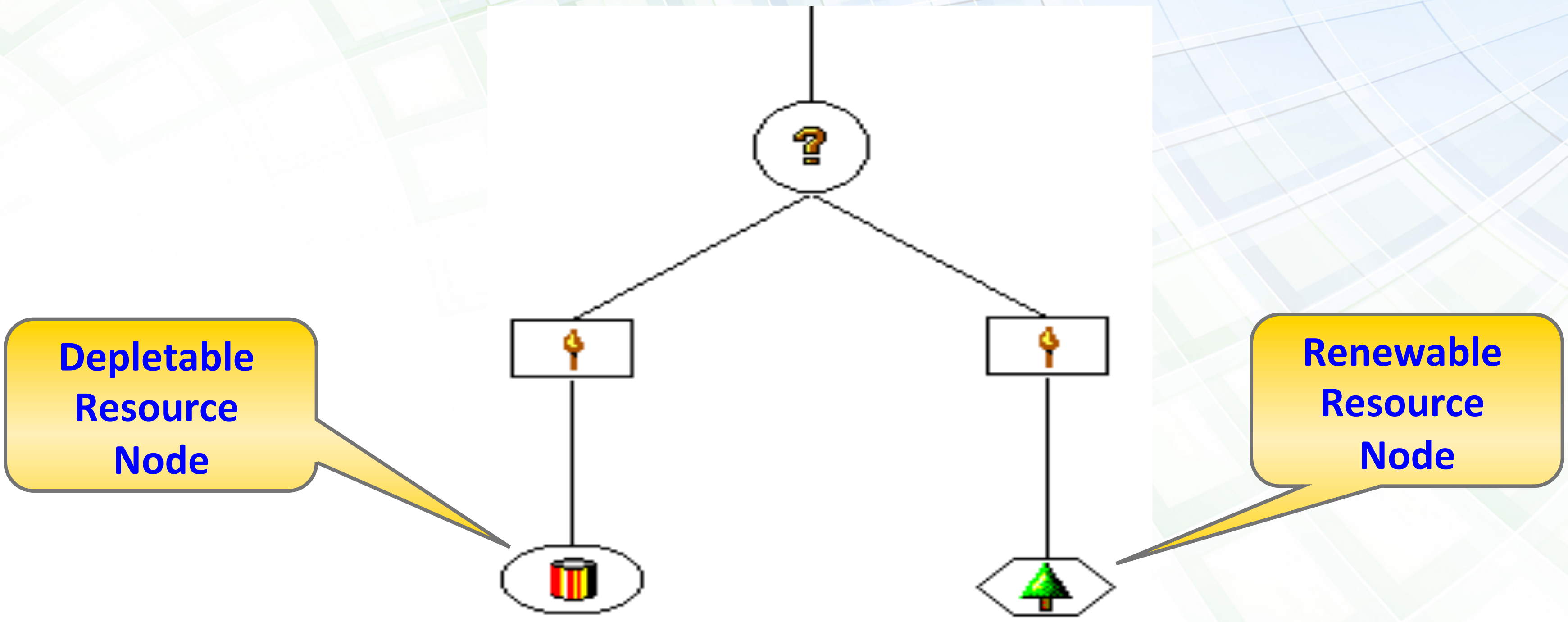
# *Node review:*

1. Resource Processes: a) depletable resources
b) renewable resources
2. Conversion Processes: a) one input, one output
b) one input, N outputs
c) N-inputs, one output
d) (transportation node)
3. Economic Processes (simulation of energy markets): a) decision (fuel/resource selection) node
b) pricing node (price corrections)
4. Energy Demand (presentation of demand projections)
5. Some other nodes/features (stockpiles, capacitated links)
6. Electricity Dispatch (simulation of central dispatch)
7. Thermal and Hydro Units (definition of technical, economic, and environmental parameters of power generation units)

This lecture

Later…

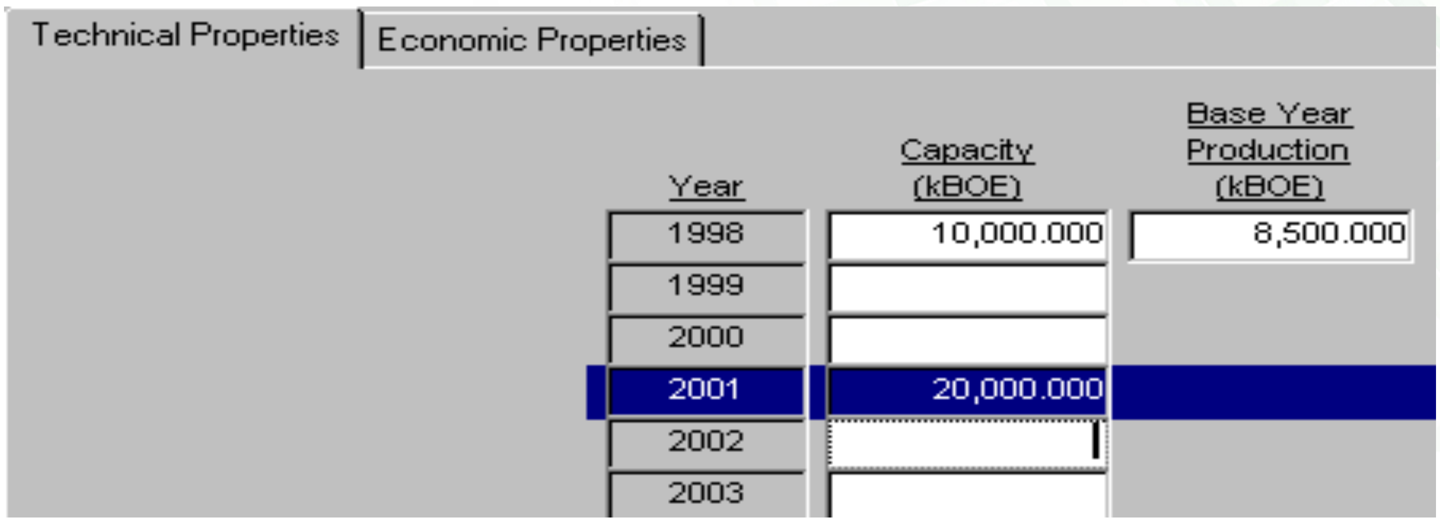
# *Resource Nodes: They are the Start of the Energy Network – Typically Located at the Bottom*




**The resource nodes have no input link and one output link**

# Depletable Resource Node: Technical Properties

- The node models domestic production and imports of depletable resources, such as crude oil, coal, or gas
- ***Capacity*** represents annual physical production limits; *it MUST be entered if the resource is available (otherwise, a blank field will mean 0*)
- Capacity can vary over time (e.g., oil field depletion, new gas fields coming on-line); *only enter values for years when capacity changes*
- ***Base Year Production*** represents the amount of the resource produced in the base year of the study; *it MUST be entered if there is some resource production in the base year (otherwise, a blank field will mean 0)*

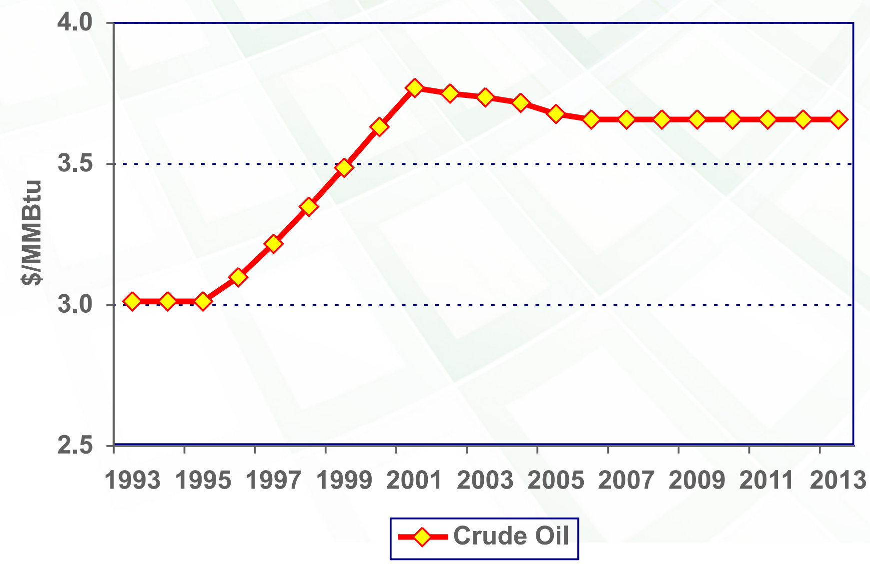


# Depletable Resource Node: Economic Properties

- ***Curve Intercept*** is the base year price of the resource
- ***Price Growth Rate*** is the price escalation over time
  - if you use real escalation rates here, you need to be consistent with other parts of the network (real escalation vs apparent escalation)
  - enter values for ALL fields
- Price projections can be obtained from various sources such as the World Bank, USDOE, IAEA, USEIA, IEA

Technical Properties | Economic Properties

| Year | Price Growth Rate (Fraction) | Curve Intercept ($/BOE) | Curve Slope | Curve Quadratic |
|---|---|---|---|---|
| 1991 | 0.010 | 19.000 | 0.000 | 0.000 |
| 1992 | 0.010 | | | |
| 1993 | 0.010 | | | |
| 1994 | 0.010 | | | |
| 1995 | 0.010 | | | |
| 1996 | 0.015 | | | |



# Depletable Resource Node: Economic Properties

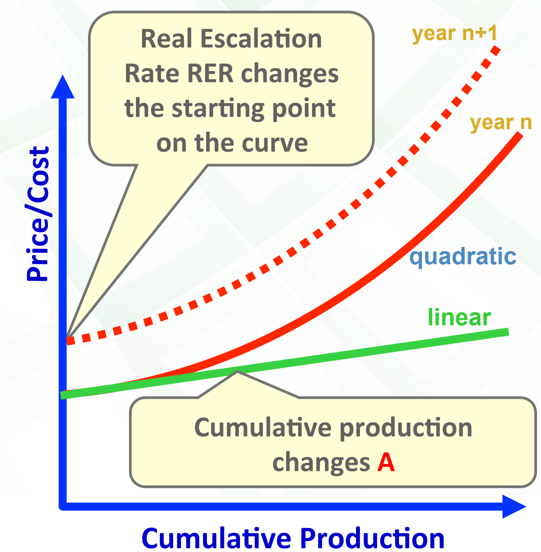
- ***Curve Slope*** and ***Curve Quadratic*** are input values to a long-run supply curve (either linear or quadratic) where the resource production cost (RPC) is a function of the previous year price (PYP), the real escalation rate (RER), the current year production quantity (CPQ), curve slope (CS), and curve quadratic (CQ)

Technical Properties | Economic Properties

| Year | Price Growth Rate (Fraction) | Curve Intercept ($/BOE) | Curve Slope | Curve Quadratic |
|---|---|---|---|---|
| 1991 | 0.010 | 19.000 | 0.000 | 0.000 |
| 1992 | 0.010 | | | |
| 1993 | 0.010 | | | |
| 1994 | 0.010 | | | |
| 1995 | 0.010 | | | |
| 1996 | 0.015 | | | |

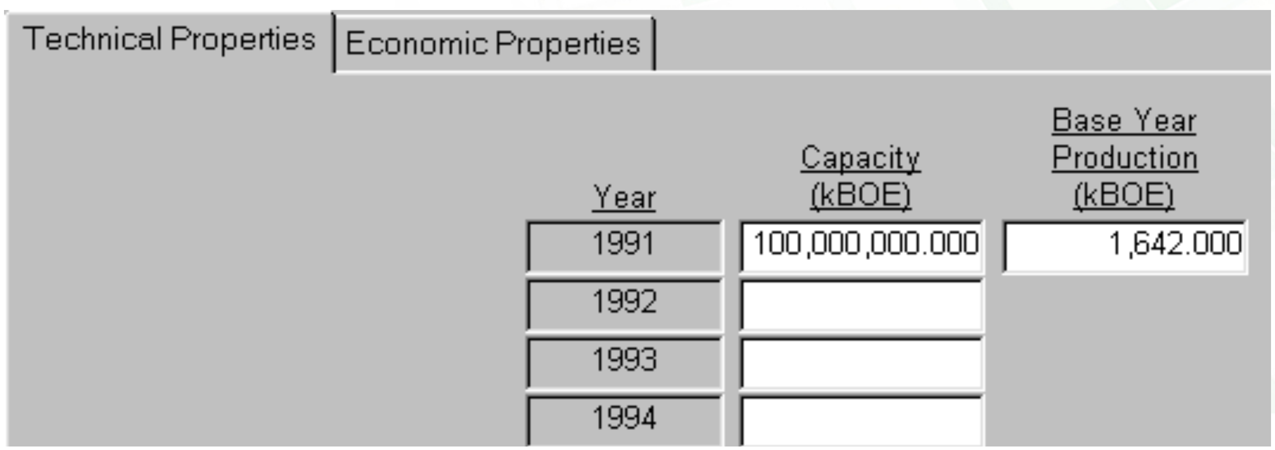
$$RPC = PYP*(1+RER) + CS*CPQ + CQ*CPQ^2$$

- PYP: intercept of the supply curve for the resource after having extracted a cumulative amount Q of the resource previous to time t
  - Adjusted at the end of each simulation year based on the amount of the resource produced
  - Initial value of PYP in the base year is taken as the price of the resource in the base year
- Supply curves can be developed for domestic resources (usually not a simple task…)
- CS and CR can be determined based on historical resource performance
- Imports can be modeled with CS and CR set to 0



# Renewable (Non-Depletable) Resource: Technical Properties

- Node models the production of renewable energy sources, such as solar, biomass, wood, etc.
- Node has one output link and no input links
- ***Capacity*** represents annual physical production limits;  only enter values for years when capacity changes
- Capacity can vary over time (e.g., amount of land devoted to wood production, new biomass plantations coming on-line)
- ***Base Year Production*** represents the amount of resource produced in the base year of the study


Technical Properties | Economic Properties

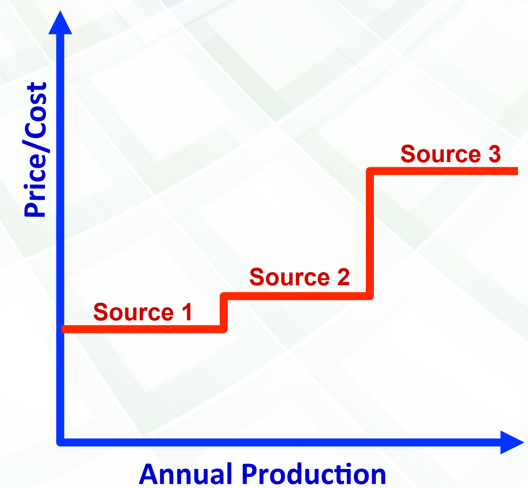
| Year | Capacity (kBOE) | Base Year Production (kBOE) |
|---|---|---|
| 1991 | 100,000,000.000 | 1,642.000 |
| 1992 | | |
| 1993 | | |
| 1994 | | |

# Renewable Resource: Economic Properties

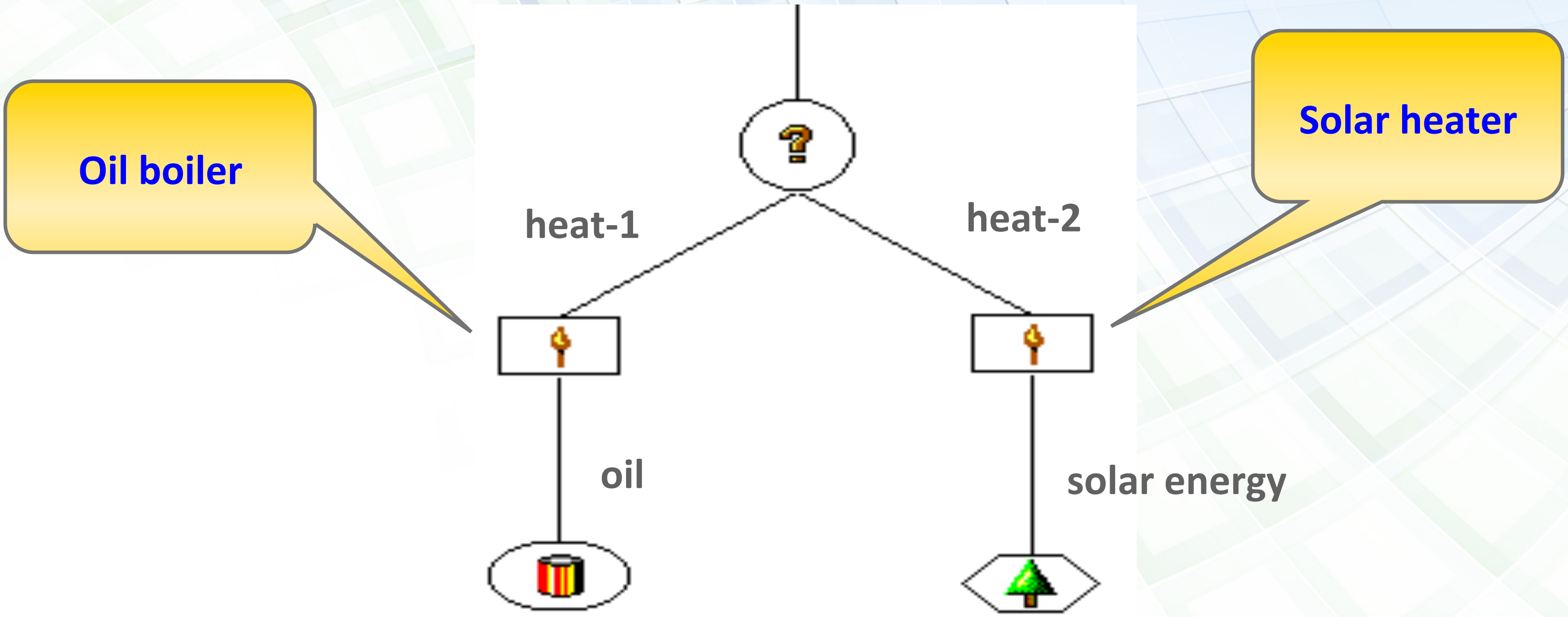
- The cost is modeled with a step function
- The step function relates the cost/price of producing the resource to the annual production of that resource; this effectively represents an annual supply curve
- Generally, each step represents a different source of production, and sources are ordered in terms of increasing costs
- ***Cost Curve Quantity*** represents the maximum annual production level at this step
- ***Cost Curve Price*** represents the price level for this level of production at this step
- ***Steps in Cost Curve*** is the number of steps for this particular resource;  the maximum is 5 steps
- NOTE: in fact, actual renewable and depletable resources can be represented with any of the two resource nodes

Technical Properties | Economic Properties

| Year | Step | Cost Curve Quantity (kBOE) | Cost Curve Price ($/BOE) | Steps in Cost Curve |
|---|---|---|---|---|
| 1998 | 1 | 3,000.000 | 15.000 | 3 |
| | 2 | 6,000.000 | 17.000 | |
| | 3 | 100,000.000 | 28.000 | |



# *Conversion Processes: They are Used to Model Transformation of Energy Resources*




There are several conversion processes available:

a) one input, one output
b) one input, N outputs
c) N-inputs, one output
d) transportation node – same as the one-to-one process

# Conversion Process / Transport Node: Technical Properties

- The node models conversion processes, such as industrial boilers, residential water heaters transportation vehicles, gas pipelines, electric trans-mission lines, etc.

Technical Properties | Economic Properties

| Year | Single Plant Output Capacity (kBOE) | All Plants Output Capacity (kBOE) | Typical Capacity Factor (Fraction) | Output/Input Ratio (Fraction) |
|---|---|---|---|---|
| 1998 | 100.000 | 10,000.000 | 0.400 | 0.400 |
| 1999 | | | | |
| 2000 | | | | 0.450 |
| 2001 | | | | |
| 2002 | | 20,000.000 | | 0.500 |
| 2003 | | | | |
| 2004 | | | | |

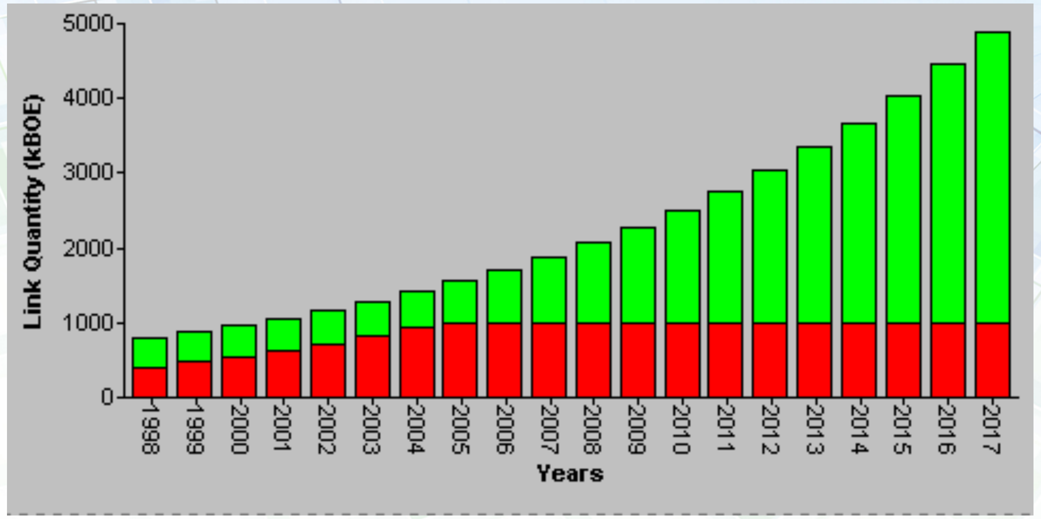
- Node has one input link and one output link (the energy at the input is converted to the energy at the output)

- ***Single Plant Output Capacity*** represents annual physical output limits of ONE unit; value is used in levelizing investment cost and computing number of units on-line in NPV routine (to be discussed later)

- The simple conversion node and the transportation node are identical by methodology; only the symbol is different (for better network representation only)

# Conversion Process / Transport Node: Technical Properties (cont'd)

- ***All Plants Output Capacity*** is the maximum output of all the units of this process
- When this limit is reached, the model will try to switch to other options to meet growing demand
- If other options also reach capacities, the model will issue a warning




- ***Typical Capacity Factor*** represents the fraction of the year this process typically operates; a value of 0.5 equals 0.5*8760 = 4380 hours; used in price calculations and NPV calculations to compute the number of units on-line and total investment costs
- ***Output/Input Ratio*** represents the conversion efficiency
- For subsequent years, only enter values when characteristics change

# Conversion Process / Transport Node: Economic Properties

- ***Single Plant Capital Investment*** represents the capital cost of **ONE** unit; this value is levelized and added to other costs, that is, fuel and O&M cost

Technical Properties | Economic Properties

| Year | Single Plant Capital Investment ($1000) | Operating and Maintenance Cost ($/BOE) | Life Expectancy (Years) | Interest Rate (Fraction) |
|---|---|---|---|---|
| 1998 | 1,000.000 | 15.000 | 21 | 0.100 |
| 1999 | | | | |
| 2000 | | 17.000 | | |
| 2001 | | | | |
| 2002 | | | | |
| 2003 | | | | |
| 2004 | | | | |

- ***Operating and Maintenance Cost (O&M)*** represents the cost of operating and maintaining **ONE** unit of this process; value is per unit of output
- ***Life Expectancy*** represents the average number of years a typical unit is expected to operate (equals the economic lifetime of the process); value is used in levelizing the capital investment cost and in NPV calculations to estimate which units are retired
- ***Interest Rate*** represents the annual interest rate used for levelizing (amortizing) the capital cost of a conversion process (cost of capital); values can be obtained from sources such local markets/banks
- For subsequent years, only enter values when characteristics change

# Conversion Process / Transport Node: Equations

- Quantity equation: conversion from input to output using process output/input ratio (efficiency)

$$Q_{Out} = Q_{In} \ x \ \eta$$

| | |
|---|---|
| **Qin:** | **Energy input** |
| **Qout:** | **Energy output** |
| **η:** | **Output/input ratio** |

- Price equation: takes input price and adds O&M costs and levelized capital costs

$$P_{Out} = \frac{P_{In}}{\eta} + O\&M + \left[\frac{TCI}{CAP_{single} \ x \ CF}\right] x \ CRF_{(i,n)}$$

$$CRF_{(i,n)} = \frac{i \ x \ (1+i)^n}{(1+i)^n - 1}$$

| | |
|---|---|
| **O&M:** | **Operating and Maintenance Costs** |
| **TCI:** | **Total Capital Investment** |
| **CAPsingle:** | **Single Plant Output Capacity** |
| **CF:** | **Capacity factor** |
| **i:** | **Interest rate (factor)** |
| **n:** | **Lifetime in years** |

# Multiple Input Process Technical Properties

- The node models the situation where fuels are blended/mixed at a fixed ratio without consideration of relative prices
- Node has one output link and up to 5 input links

Technical Properties | Economic Properties

| Year | Input Link Abbreviation | Input/Output Ratio | Single Plant Output Capacity (kBOE) | Output Capacity of All Plants (kBOE) | Typical Capacity Factor (Fraction) |
|---|---|---|---|---|---|
| 2000 | GSLR | 0.796 | 100.000 | 1,000.000 | 0.600 |
| | OLNG2 | 0.204 | | | |
| 2001 | GSLR | | | | |
| | OLNG2 | | | | |
| 2002 | GSLR | | | | |

- Examples for multiple input processes
  - solar heater in the household sector that has LPG as a backup fuel
  - blending of gasoline and ethanol to produce gasohol in the transport sector
  - preprocessing of heavy crude by spiking it with lighter fractions in the oil sector
- ***Input/Output Ratio*** represents the amount of input quantity per unit of output for each input link connected to the node
  - the sum of the input/output ratios has to be at least 1.0
  - the fraction above 1.0 represents the losses in the blending

# Multiple Input Process Technical Properties (cont'd)

- ***Single Plant Output Capacity*** represents the physical annual output limits of **ONE** unit; value is used in levelizing investment cost and NPV calculations for the number of units online
- ***Output Capacity of all Plants*** is the maximum output of **ALL** the units
  - when this limit is reached, the model will switch to other options to meet growing demand
  - if other options also reach capacities, the model will issue a warning
- ***Typical Capacity Factor*** represents the fraction of the year this process typically operates; a value of 0.5 equals 0.5*8760 = 4380 hours; used in price calculations and NPV calculations to compute the number of units on-line and total investment costs

Technical Properties | Economic Properties

| Year | Input Link Abbreviation | Input/Output Ratio | Single Plant Output Capacity (kBOE) | Output Capacity of All Plants (kBOE) | Typical Capacity Factor (Fraction) |
|---|---|---|---|---|---|
| 2000 | GSLR | 0.796 | 100.000 | 1,000.000 | 0.600 |
| | OLNG2 | 0.204 | | | |
| 2001 | GSLR | | | | |
| | OLNG2 | | | | |
| 2002 | GSLR | | | | |

# Multiple Input Process Economic Properties

- ***Single Plant Capital Investment*** represents the capital cost of **ONE** unit; this value is levelized and added to other costs that is, fuel and O&M

Technical Properties | Economic Properties

| Year | Single Plant Capital Investment ($1000) | Operating and Maintenance Cost ($/BOE) | Life Expectancy (Years) | Interest Rate (Fraction) |
|---|---|---|---|---|
| 2000 | 101.000 | 12.000 | 21 | 0.100 |
| 2001 | | | | |
| 2002 | | | | |
| 2003 | | | | |
| 2004 | | | | |

- ***Operating and Maintenance Cost (O&M)*** represents the cost of operating and maintaining **ONE** unit of this process; value is per unit of output
- ***Life Expectancy*** represents the average number of years a typical unit is expected to operate (equals the economic lifetime of the process); value is used in levelizing the capital investment cost and in the NPV-economic cost routine
- ***Interest Rate*** represents the annual interest rate used for levelizing (amortizing) the capital cost of a conversion process (cost of capital); values can be obtained from sources such as local markets/banks or the World Bank (Note: Use real interest rate if you use real price escalations for resources!)
- For subsequent years, only enter values when characteristics change

# Multiple Input Process Equations

- Quantity equation: conversion from input to output using process output/input ratio (efficiency)
- Example of multiple input process: A solar heater with LPG back-up; This process has two inputs (solar and LPG) and one output (heat)

$$Q_{Out,\,L1} = \frac{Q_{In}}{IO_{ratio_{L1}}}$$

**Qin:** **Energy input**
**Qout,L1:** **Energy output on link 1**
$IO_{ratio,\,L1}$: **Input/output ratio for link 1**

- Price equation: takes input price(s) and adds O&M costs and levelized capital costs

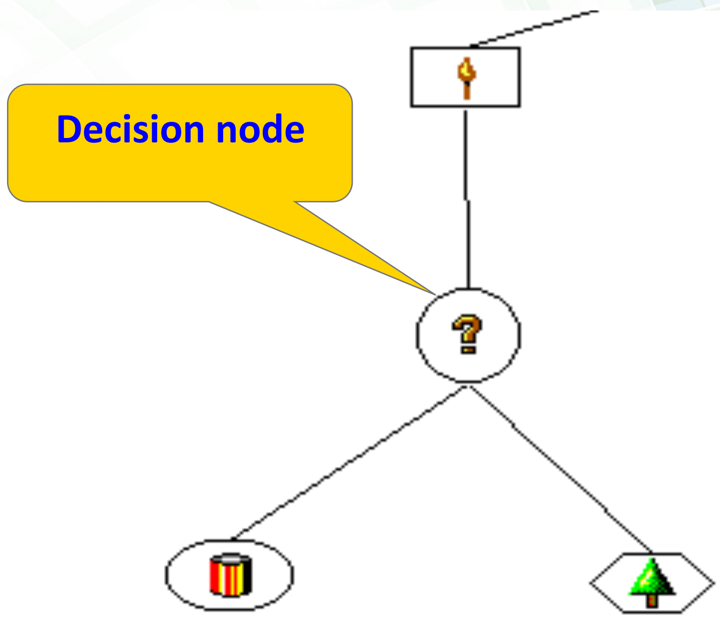
$$P_{Out} = \frac{P_{In,L1}}{OI_{ratio,L1}} + \frac{P_{In,L2}}{OI_{ratio,L2}} + O\&M + \left[\frac{TCI}{CAP_{single}\ x\ CF}\right] x\ CRF_{(i,n)}$$

**$P_{in,\,L1}$:** **Price of input fuel on link 1**
**$Oi_{ratio,\,L1}$:** **Output/input ratio on link 1**
**O&M:** **Operating and Maintenance Costs**

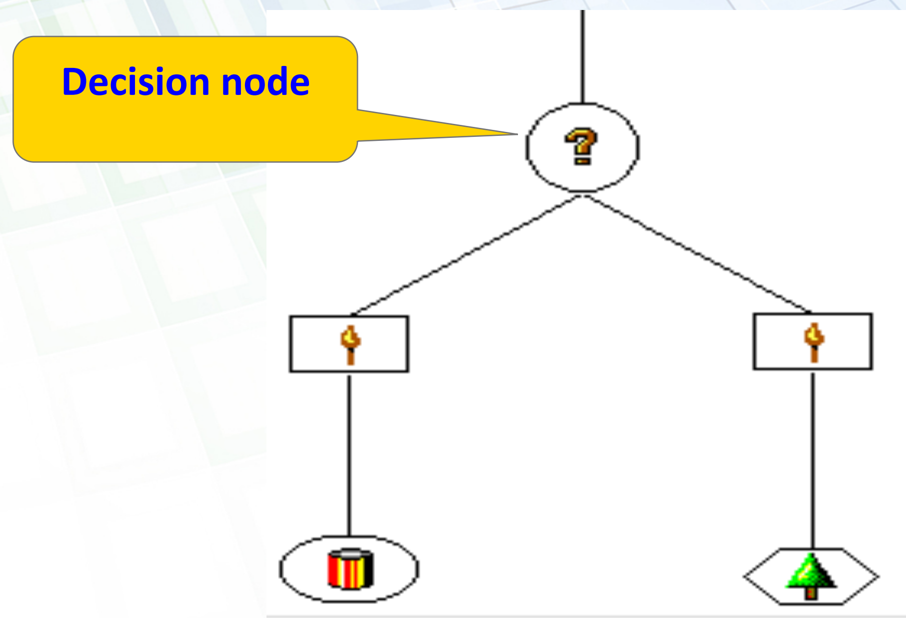
**TCI:** **Total Capital Investment**
**CAPsingle:** **Single Plant Output Capacity**
**CF:** **Capacity factor**
**CRF:** **Capital recovery factor**

# Economic Processes: Decision (or Allocation) Node

**Example 1:**
**Two Resources Competing**

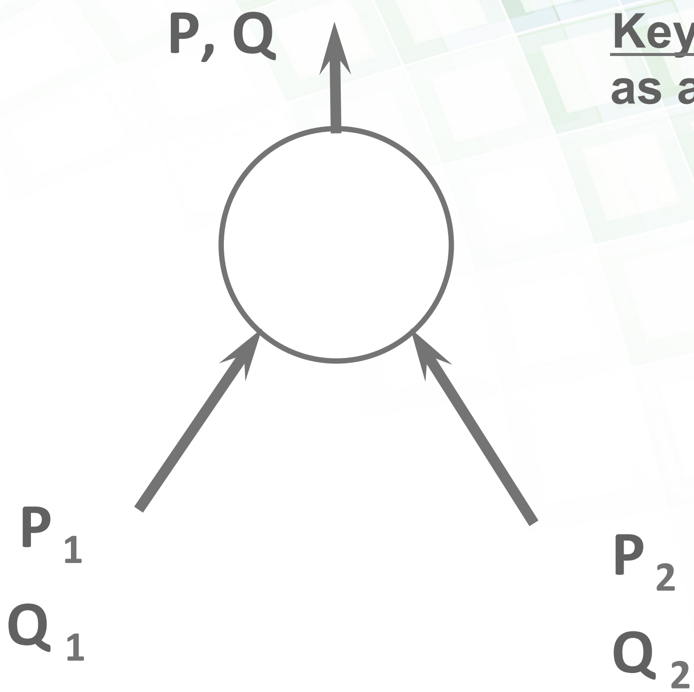



**Example 2:**
**Two Energy Products Competing**




- The need to select a mix of energy resources appears in many parts of the network
- The principal issue is to determine the outcome of the competition/selection among multiple options/choices

# *Two Resources are Competing; The Key Parameters are Quantities and Prices*




<u>Key question</u>: How to determine Q1 and Q2 as a function of Q (the demand), P1, and P2 (the prices)?

=> The decision node uses a market share algorithm.

**The Decision Node that solves this problem is the core node of the energy system model**

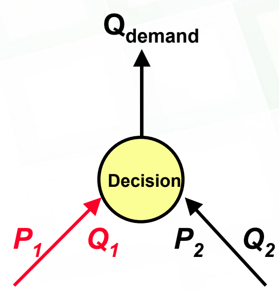
# A Non-Linear Equilibrium Algorithm to Determine the Energy Supply Mix that is Used

$$MS_1 = \frac{Q_1}{Q_1 + Q_2} = \frac{\left(\frac{1}{P_1}\right)^{\gamma}}{\left(\frac{1}{P_1}\right)^{\gamma} + \left(\frac{1}{P_2}\right)^{\gamma}}$$

$P_1 = P_2$ => $Q_1 = Q_2$ (equal prices => equal shares)
$P_1 > P_2$ => $Q_1 < Q_2$ (higher price => lower share)
$\gamma$ - regulates the intensity of the response to prices

# The Simple Algorithm has Additional Features to Allow for Various Factors to be Considered

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




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

- Market share calculation assumes an "ideal market" but may be subject to parameters, such as government policies, fuel availability, and market constraints
- Premium multipliers (PM) allow to introduce preferences through price correction
- A lag factor (LF) accounts for delays in capital stock turnover: DQ(market) = LF x Q(total), i.e., only a portion of the total quantity will be affected by the shown market share formula
- The result is a nonlinear, market-based equilibrium solution within policy constraints, not a linear optimization

# Decision (Allocation) Node

- Decision/allocation node is among the most important nodes in defining the role competing fuels and energy technologies will play in a future energy system
- Node represents the market forces at play when choices are made to use a particular type of energy
- Node selects the amount of fuel to be supplied from competing sources on the input links of the node (DECISION), and routes the energy to satisfy energy flow requirements on the output links (ALLOCATION)
- Examples for decision nodes include:
  - petroleum products from domestic refineries versus imports in the oil sector
  - charcoal produced from wood and agricultural residues in the distribution sector
  - auto-travel demand met by gasoline and diesel autos in the transport sector
  - cooking heat requirements satisfied by charcoal, kerosene, natural gas, wood, electricity, and LPG in the household sector
  - on-site generation and grid-produced electricity in the industry sector

# Decision and Allocation Node Technical Properties

- Node has up to 10 input links and up to 10 output links
- ***Priority*** represents the user-specified order in which the decision node allocates a demand quantity to supply sources (input links)
  - government policies may override allocation decisions based strictly on relative prices
  - a government may have a policy in place to use domestically refined petroleum products rather than imported products (usually made to protect local jobs)

Technical Properties | Economic Properties

| Year | Input Link Abbreviation | Priority | Premium Multiplier | Output Link Abbreviation | Base Year Split (Fraction) |
|---|---|---|---|---|---|
| 2000 | FOIL | 1 | | FUEL3 | 0.500 |
| | FOIL1 | 2 | | LN301 | 0.500 |
| 2001 | FOIL | | | | |
| | FOIL1 | | | | |
| 2002 | FOIL | | | | |
| | FOIL1 | | | | |
| 2003 | FOIL | | | | |

- This priority allocation is done without regard to the relative prices on the input links – if Priority is defined, the market share formula does **NOT** work
- A quantity is allocated to an input link up to the capacity of the source, if a capacity exists
- This procedure is repeated until the entire net output quantity has been allocated to all input links

# Decision and Allocation Node Technical Properties (cont'd)

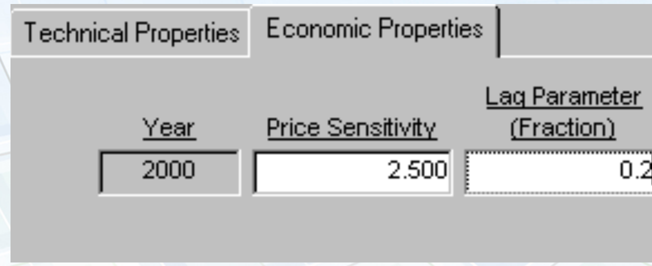
- ***Premium Multiplier*** represents non-price factors that affect decisions
  - VW Beetle versus Porsche
  - kerosene lighting versus electric lighting
- Values for premium multipliers can be obtained from analyzing historical data (e.g., base year or base period) using the MSHARE routine or from "expert judgement"
- When entering values, one of the multipliers should be 1.0
- The default value is 1.0;  do NOT enter 0 in any of these fields
- ***Base Year Split*** represents the fraction of total supply allocated to each of the output links in the base year; the model uses this value only in the base year calculations
- Base year splits need to sum up to 1.0;  if there is only one output link, you **MUST** enter 1.0

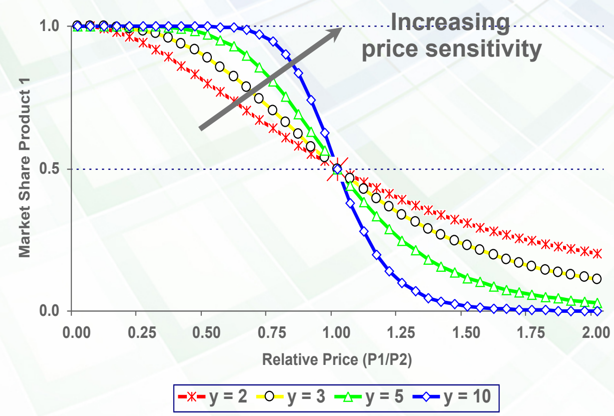
Technical Properties | Economic Properties

| Year | Input Link Abbreviation | Priority | Premium Multiplier | Output Link Abbreviation | Base Year Split (Fraction) |
|---|---|---|---|---|---|
| 1998 | LN1 | | 1.500 | LN3 | 0.500 |
| | LN2 | | 1.000 | LN9 | 0.500 |
| 1999 | LN1 | | | | |
| | LN2 | | | | |

# Decision and Allocation Node Economic Properties

- The ***Price Sensitivity*** parameter, $\gamma$, in the market share equation determines the degree to which differences in relative prices lead to differences in market share
- In some situations, there is significant sensitivity to price differences
  – Small changes in relative price will produce fairly large changes in market share
  – Example: a refinery purchasing crude oil
- Other market segments are not as sensitive to price changes
  – Large changes in relative price are needed to produce a noticeable change in shares
  – Example: gas vs. electric cooking

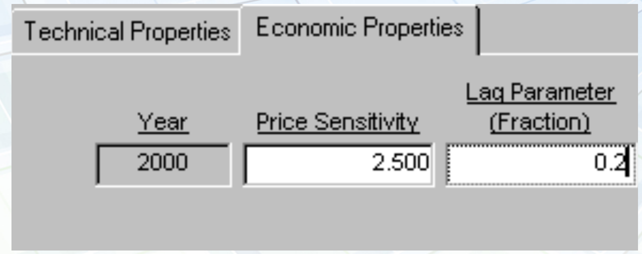


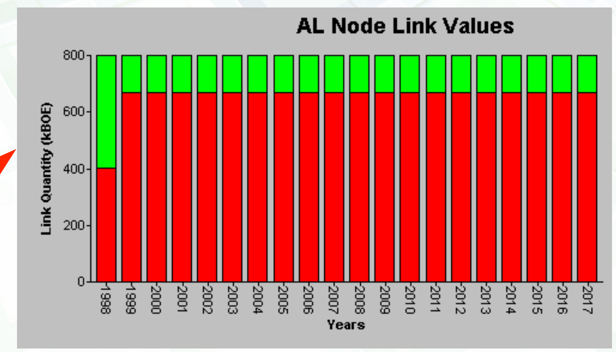



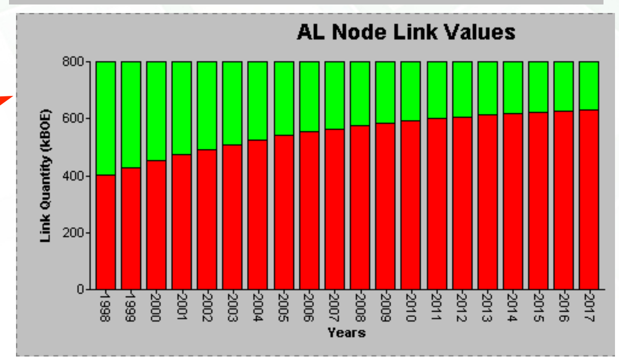

- Values can be obtained from analyzing historical market shares and relative prices for each of the critical decision nodes in the network
  – A value of 0 keeps the market shares constant regardless of the relative prices
  – The maximum value of 15 approximates a situation in which 100% of the quantity is allocated to the least-cost source (even if the price difference is small)

# Decision and Allocation Node Economic Properties (cont’d)

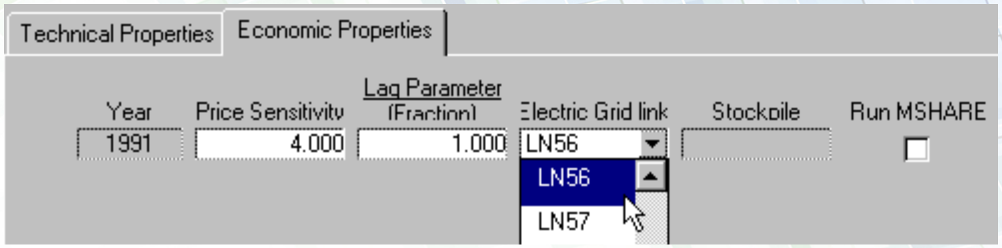
- The ***Lag Parameter*** models situations where a particular market cannot readily respond to price signals (even to large price changes); it represents the lag or delay that often occurs between a change in relative prices and an observed change in market shares
- Existing capital stock or limited access to the cheaper fuel are examples of circum-stances that prevent market response
- Lag determines what portion of the market is able to adjust to a change in prices
  - 0 means no response, model will keep the base year shares
  - 1.0 means immediate response
  - 0.1 means 10% of the market shift can actually occur per year – gradual change

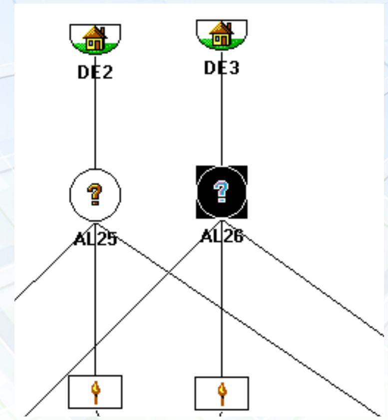


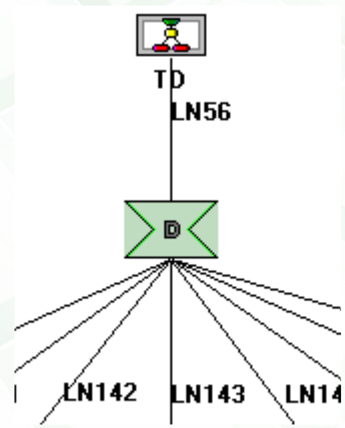



# Decision and Allocation Node Economic Properties (cont'd)



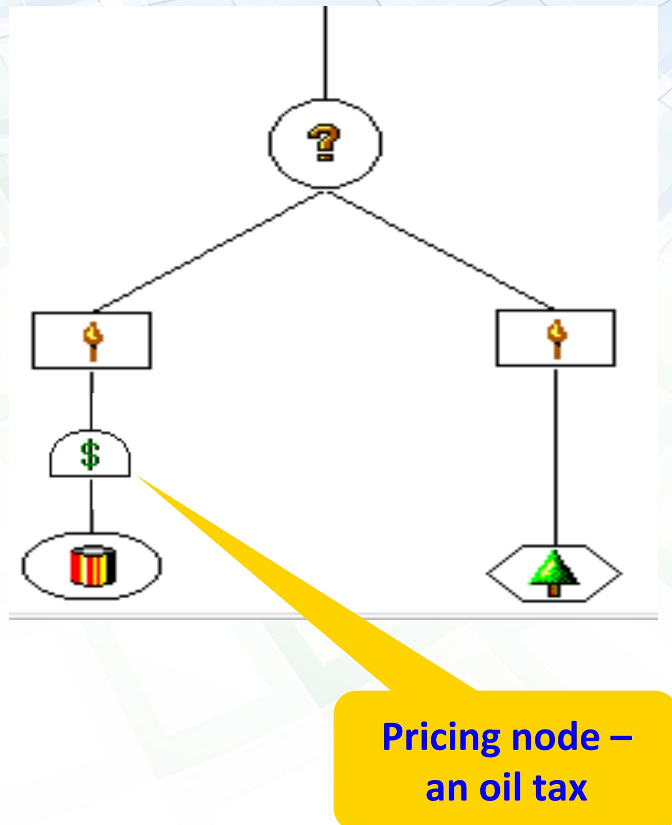



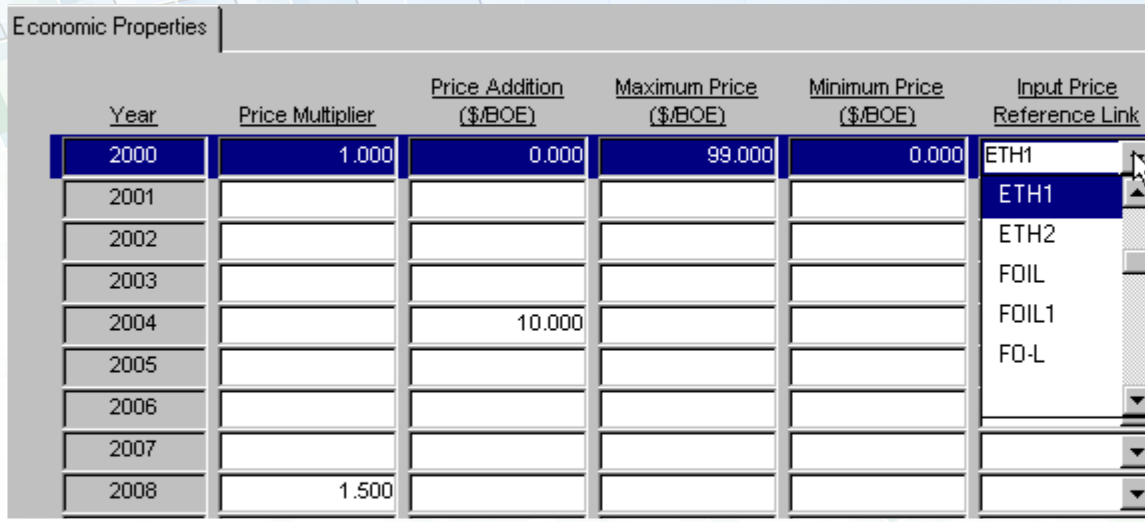

- ***Electric Grid Link*** may be used if a decision node has at least two input links, one link for central grid electricity and the other for decentralized electricity generation, such as on-site industrial diesel generators
- If the link is selected and the capacity specified for the decentralized source is not exceeded, but the decentralized electricity is cheaper than the grid electricity, the decentralized source is assumed to produce at its full capacity
- Excess power is routed through the decision node as a negative quantity and assigned to the grid link; effectively reducing the demand for grid electricity

# Pricing Node - 2nd Economic Node Economic Properties

- The node is used to simulate a government tax (e.g., on petroleum products), subsidy (on domestic coal), price ceiling, price floor, or other government pricing policy
- Node has one input link and one output link
- A pricing node does NOT affect the quantity on the links
- A pricing node changes only the PRICE on the output link of the node



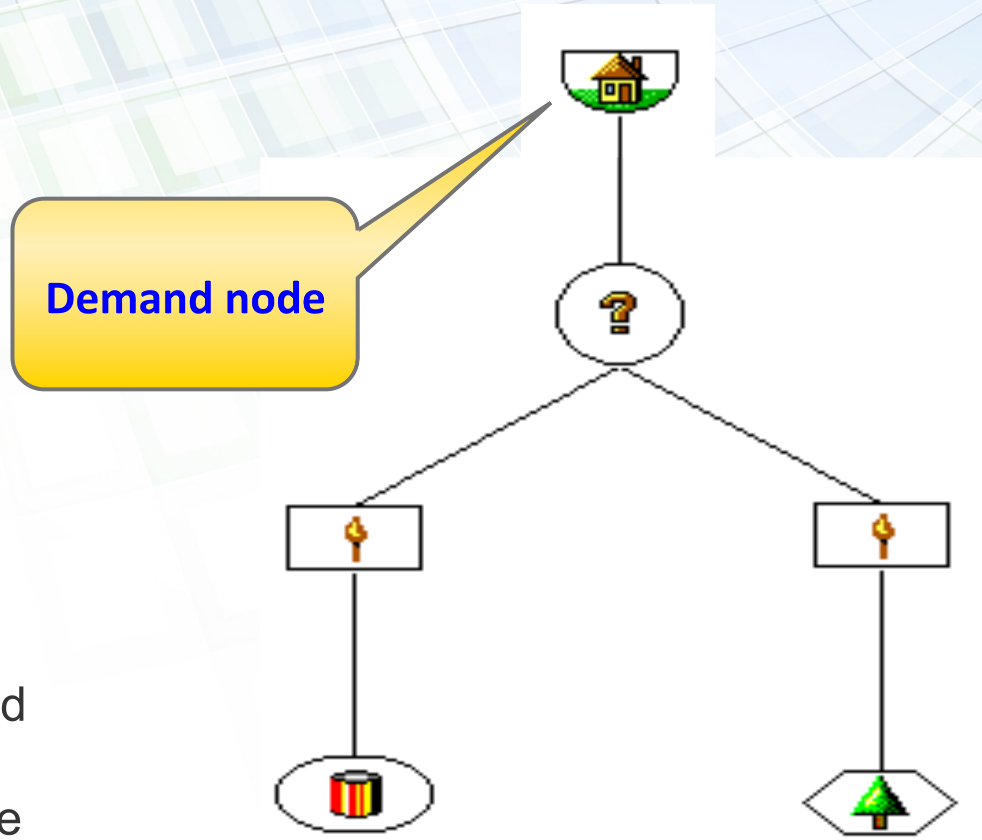
# Pricing Node Economic Properties




- A ***Price Multiplier*** of less than 1.0 indicates a subsidy, and a value greater than 1.0 indicates a tax
- A ***Price Addition*** of less than 0 indi-cates a subsidy, and a value greater than 0 indicates a tax
- A ***Maximum Price*** is used to implement a price ceiling;  the price on the node output link will not exceed this value
- A ***Minimum Price*** is used to represent a price floor;  the price on the node output link will be at least this value
- ***Input Price Reference Link***: In many cases, the reference link may be the input link to the pricing node;  however, if necessary, it can be any link in the network

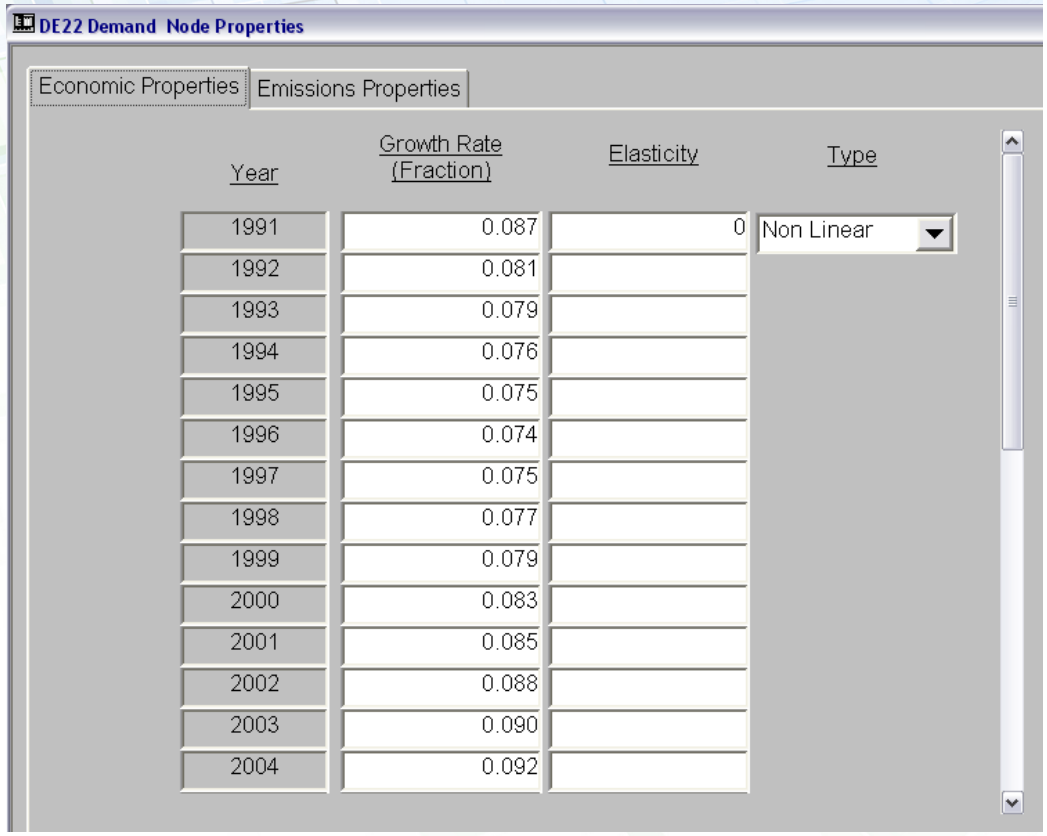
# Demand Node

- The node models demands for any type of final energy carriers (e.g., electricity) or useful energy demands, such as demands for residential heat, industrial steam, passenger transportation, etc.
- Node has one input link and no output link
- Demand nodes are typically positioned at the top of the network, that is, at points where energy flows terminate



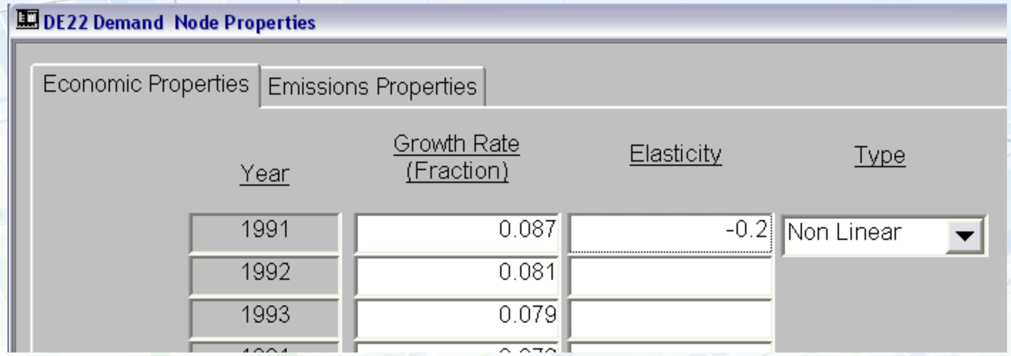
# Demand Node Economic Properties

- ***Growth Rate*** represents the growth rate in energy demand between successive years in the study period; ALL fields need to be entered
- The first growth rate should represent the growth between the first and the second year
- A value of 0.087 in the 1991 field indicates the demand in the year 1992 will be 8.7% higher than in 1991

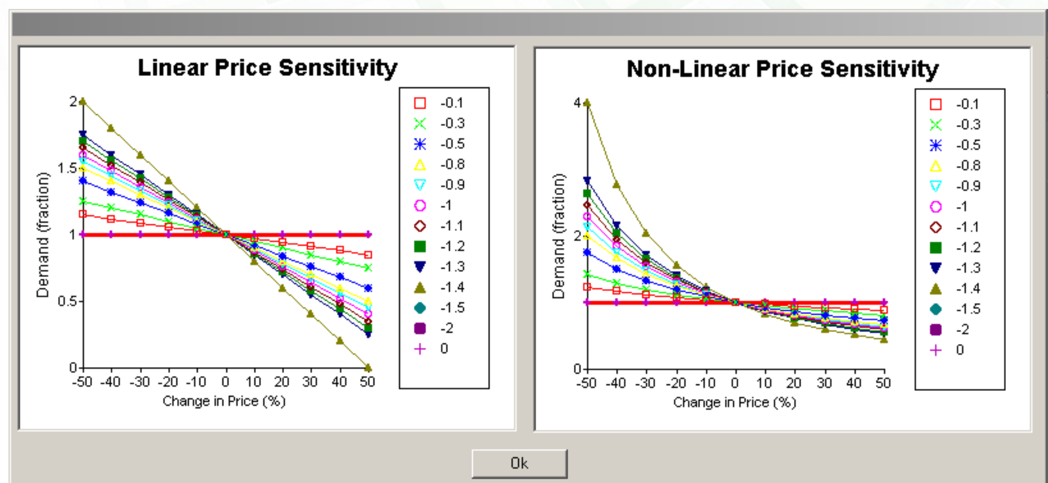


# Demand Node Economic Properties

- ***Elasticity*** represents the price elasticity of energy demand;
  - Entered as a fraction
  - Percentage change in demand for each percent change in price
  - Negative value means with increase in price, demand goes down
    - Value of -0.2 means demand drops by 0.2% for each price increase of 1%

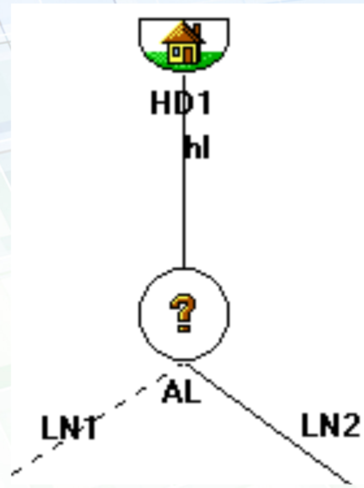



- The model offers two options
  - Linear (for smaller changes in price)
  - Non-linear (for larger changes in prices)

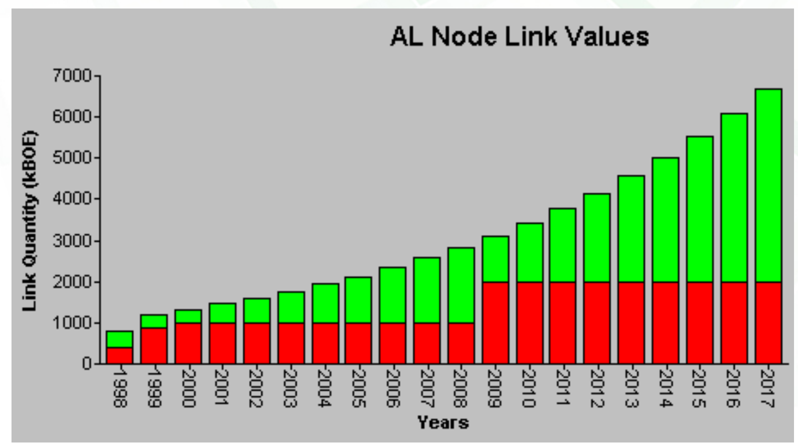


# *Capacitated Links: Links with Limited Energy Flow Capacity (Constrained Links)*

- User can capacitate links ONLY if they are input links to a decision node
- Double-click an input link to a decision node and enter capacity
- Link Capacity is the maximum energy flow on this link; can change over time
- Once the quantity on the link reaches the capacity, the remaining growth in demand will be covered by alternative links (if available)
- Please note that if there are no supply alternatives available, there will be a model IMBALANCE: a warning will be issued during the iteration as well as in some of the output files
- Similarly, if all input links are capacitated and the total exceeds the sum of all capacities, the model will issue a warning




| Year | Link Capacity (kBOE) |
|---|---|
| 1998 | 1,000.000 |
| 1999 | |
| 2000 | |
| 2001 | |
| 2002 | |
| 2003 | |
| 2004 | |
| 2005 | |
| 2006 | |
| 2007 | |
| 2008 | |
| 2009 | 2,000.000 |
| 2010 | |



# Summary

- Resource nodes: there are two resource nodes (depletable and renewable resource nodes); they differ in the form of the cost function (quadratic or step function)
- Conversion nodes: there are one-to-one, one-to-several, and several-to-one conversion nodes
- Economic nodes:
  - Decision/allocation nodes: The principal node largely determining the BALANCE outcome. Decision nodes should be validated
  - Pricing nodes: The node is attractive but should be used with caution because it can distort results or hide important factors
- Demand nodes: The node is the simplest; the only caution is to use the correct growth rates, and enter values for every year
- Stockpile nodes: The node is useful for modeling refineries and similar objects, but this is NOT a real stockpile
- Capacitated links: They can be useful for introducing constraints, but be careful: the constraints often relate to objects, not links
- Electric nodes: To be covered in the lecture on the electric sector…

# Handout: List of BALANCE Equations

| NODE | PRICE EQUATION | QUANTITY EQUATION |
|---|---|---|
| **RS** | $Pout_t = A(Qout_{t-1}) \times (1 + R_t) + B \times Qout_t + C \times Qout_t^2$ | $Qout_0$ in the base year is user-specified. |
| **RN** | $Pout_t = C_i$ if $Qout_t <= L_i$, where i = 1 to 5 | $Qout_0$ in the base year is user-specified. |
| **PR** | $Pout_t = Pin_t /f + OM + [TCI/(CAP \times CF)] \times CRF(i,n)$ | $Qout_t = Qin_t \times f$ |
| **RE** | Method 1: $Pout_{(t,o)} = Pin_t \times w_0$<br>Method 2: $Pout_{(t,k)} = [\, Pin_t /s_k + OM/s_k + [TCI/(CAP \times CF \times s_k)] \times CRF(i,n)] \times (1+PFF) - \Sigma_{o \neq k\ [(so}/s_k) \times P_o]$<br>$Pout_{(t,o)} = Pin_{(t,k)} \times w_o$, for the remaining output links | $Qin_t = \sum_o [Qout_{(t,o)} \times s_o]$ |
| **ST** | The price is 0 for stockpiled products. | ST nodes store the excess product produced by refinery nodes. The link of an ST node must be an input to some allocation node of the network. Each year, the allocation node removes as much of the product as possible to meet the required demand. Any remaining demand is met by the other supply alternatives of the allocation node. |
| **MI** | $Pout_t = \sum_l [Pin_{(t,l)} \times IO_l] + OM + [TCI / (CAP \times CF)] \times CRF(i,n)$ | $Qin_{(t,l)} = Qout_t \times IO_l$ |
| **AL** | $Pout_{(t,o)} = \sum_l [P_l \times S_l]$<br>In other words, the weighted average price over all supply alternatives is used as the price on all output links. | The AL node first meets the quantity demanded by available stocks, additional demand is met based on the user-specified priority up to the capacity limits of the supply alternatives remaining demand is then allocated based on relative market shares:<br>$Qin_{(t,l)} = NQ \times [S_l \times LAG + OMS \times (1–LAG)]$<br>$S_l = [1/(P_l \times PM_l)^r ]/ \sum_l [1/(P_l \times PM_l)^r]$ |

# Handout: List of BALANCE Equations

| NODE | PRICE EQUATION | QUANTITY EQUATION |
| --- | --- | --- |
| **PP** | $Pout_t = a \times P_l + b$, where Price Floor < = $Pout_t$ < = Price Ceiling | $Qin_t = Qout_t$ |
| **DE** | Prices are not adjusted at the DE node | $Qin_0$ is calculated on the up pass in the base year, for the remaining years $Qin_{(t)} = Qin_{(t-1)} \times (1+D_t)$ |