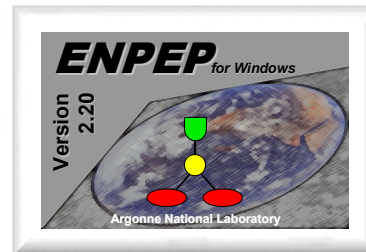


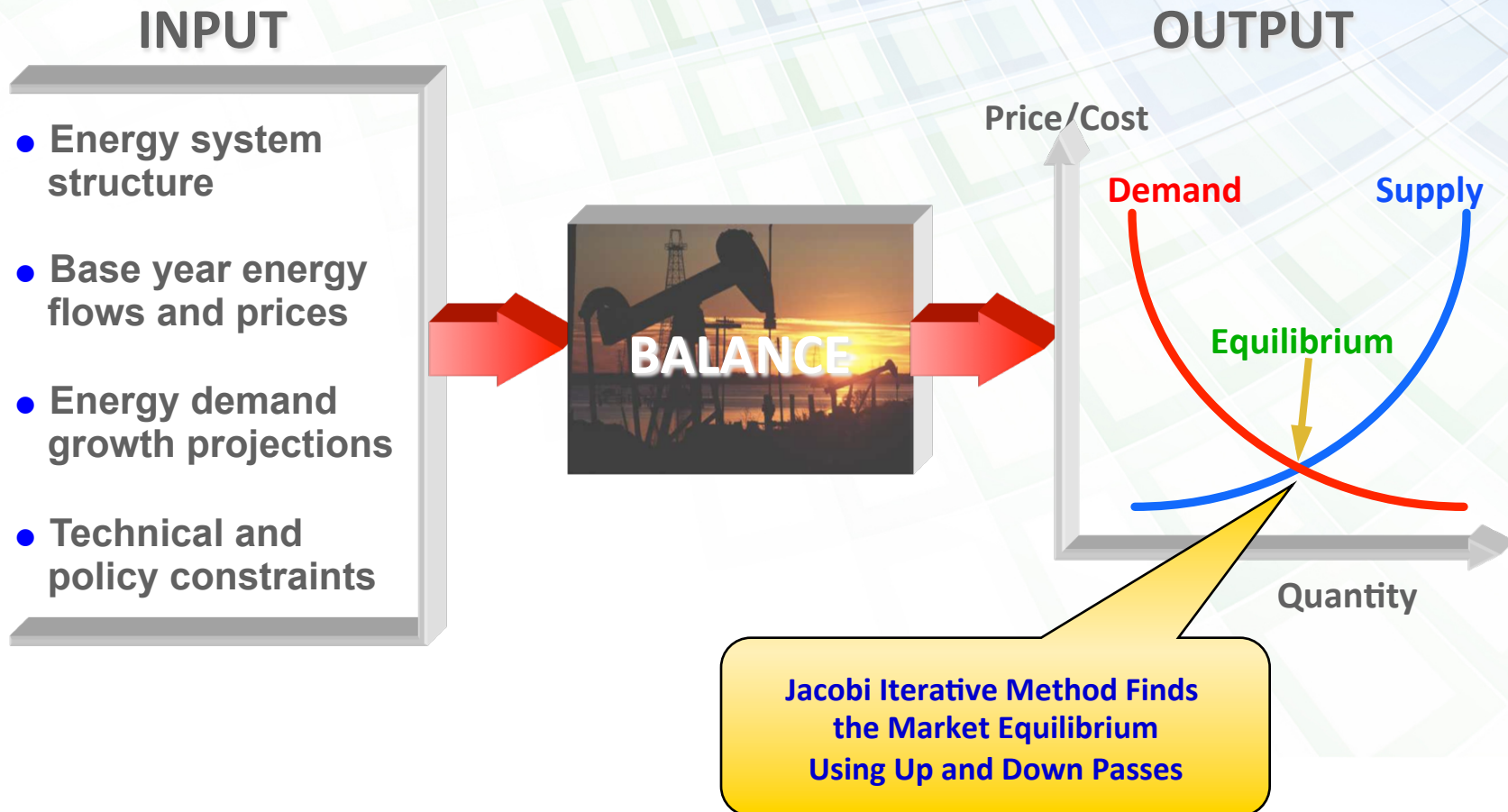
ENPEP-BALANCE: Up and Down Pass

ENPEP-BALANCE Training Course
Singapore
December 5-9, 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
guenter@anl.gov; ++1-630-252-7173

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



The Status of Iterations is Shown to the User as BALANCE Proceeds with Calculations

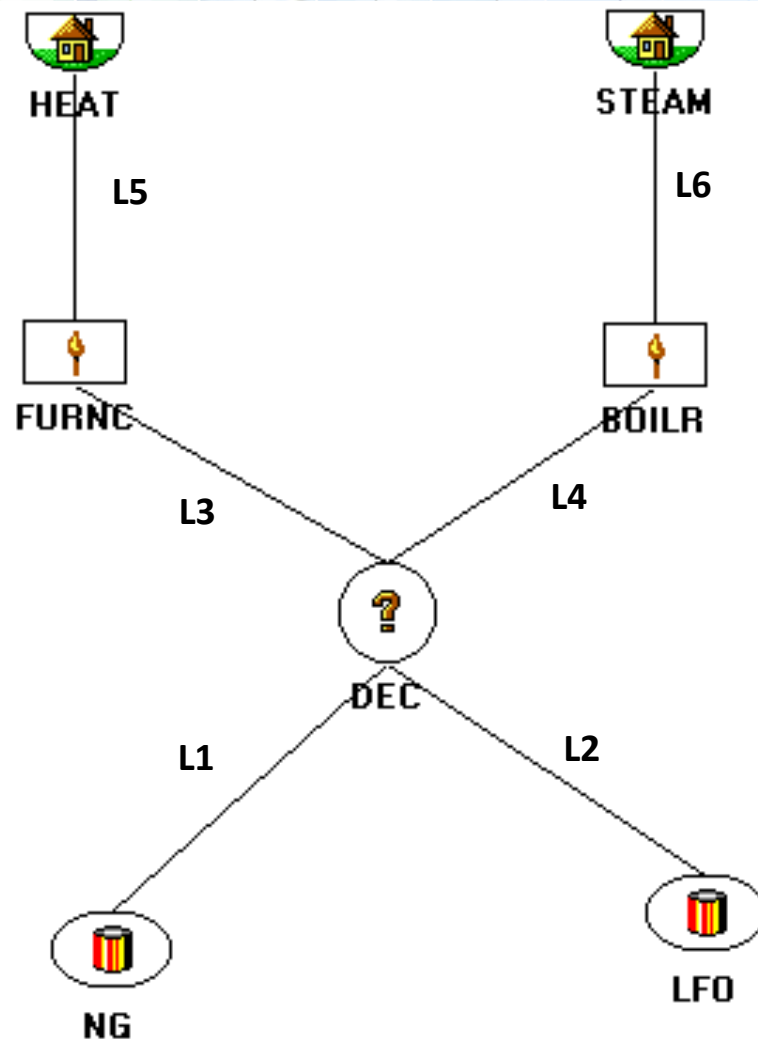
Simulation Status

The requested simulation run is complete:

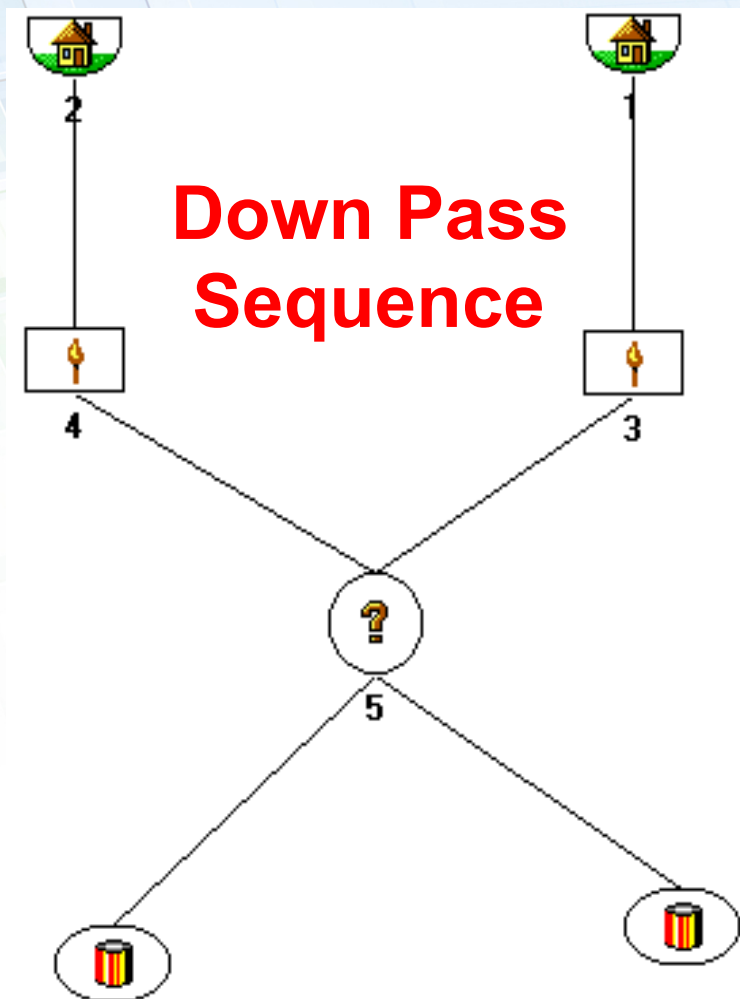
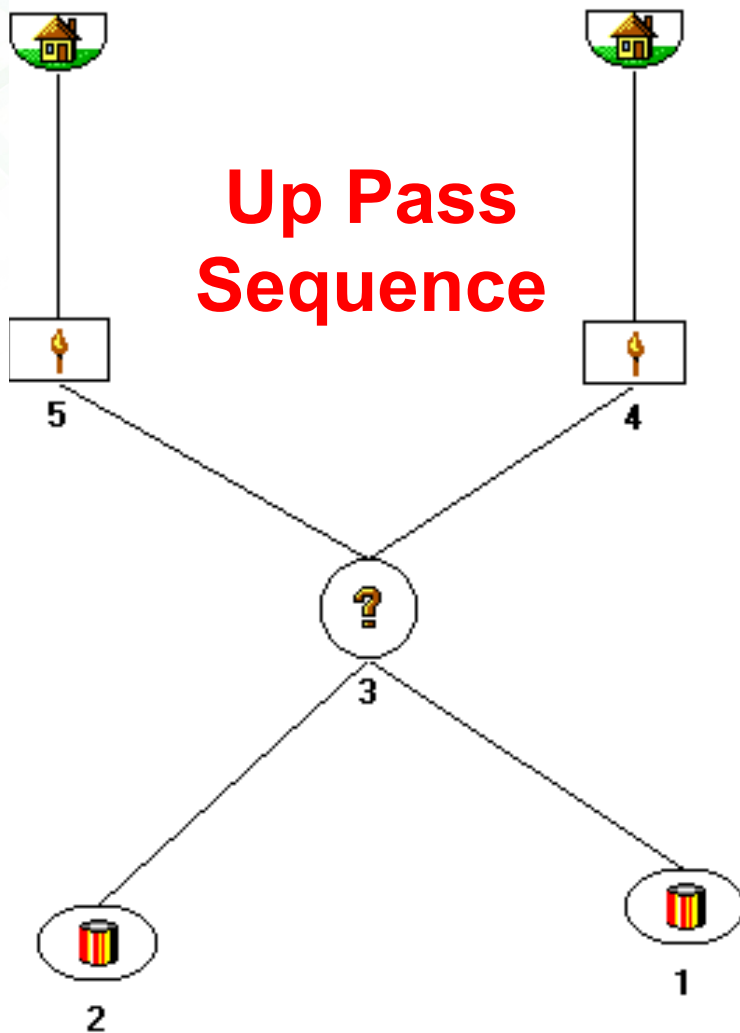
Status Display for the Iterations

| | | | | |
|------|-------------------------------------------------------------------------------|------------------------------|-----------------|---|
| 2008 | ITERATION = 1 | MAX REL ERR = -4.743746e-001 | ABS ERR = 474.4 | # |
| 2008 | ITERATION = 2 | MAX REL ERR = -3.072444e-001 | ABS ERR = 234.4 | # |
| 2008 | ITERATION = 3 | MAX REL ERR = -3.290778e-002 | ABS ERR = 18.2 | # |
| 2008 | ITERATION = 4 | MAX REL ERR = -2.269972e-003 | ABS ERR = 18.2 | # |
| 2008 | CONVERGENCE AT REL. TOL. = 0.010000 AND ABS. TOL. = 1.0 AFTER 4 ITERATIONS. # | | | |
| 2009 | ITERATION = 1 | MAX REL ERR = -4.734077e-001 | ABS ERR = 253.5 | # |
| 2009 | ITERATION = 2 | MAX REL ERR = -3.075564e-001 | ABS ERR = 125.7 | # |
| 2009 | ITERATION = 3 | MAX REL ERR = -3.794662e-002 | ABS ERR = 11.2 | # |
| 2009 | ITERATION = 4 | MAX REL ERR = -3.416705e-003 | ABS ERR = 11.2 | # |
| 2009 | CONVERGENCE AT REL. TOL. = 0.010000 AND ABS. TOL. = 1.0 AFTER 4 ITERATIONS. # | | | |
| 2010 | ITERATION = 1 | MAX REL ERR = -4.698272e-001 | ABS ERR = 134.1 | # |
| 2010 | ITERATION = 2 | MAX REL ERR = -3.048807e-001 | ABS ERR = 66.6 | # |
| 2010 | ITERATION = 3 | MAX REL ERR = -3.876605e-002 | ABS ERR = 6.1 | # |

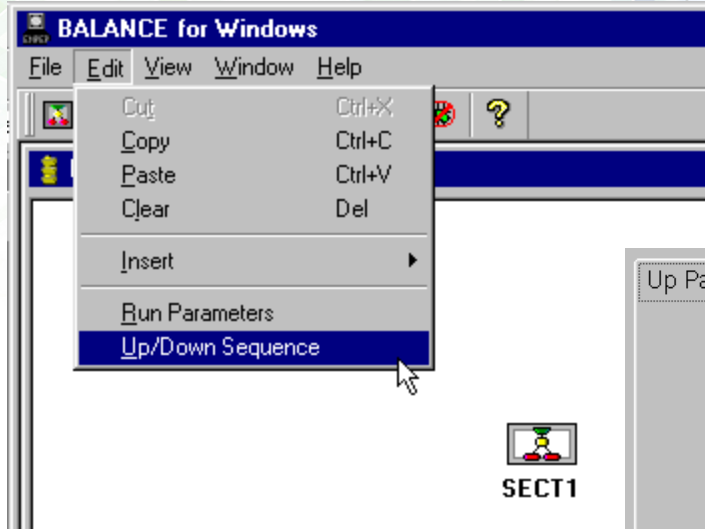
The Up and Down Pass Calculations to be Performed on a Simple Network



Up and Down Pass Sequences Used for Calculations



You Can View and Edit the Up and Down Pass Sequences



You usually need to edit the sequence only if you have cogeneration in the network. Also it may be necessary in some situations with the oil refinery.

| Up Pass Sequence | | | | | |
|------------------|-------------------|-----------------|---------------------|-------------|-------------|
| Node Type | Node Abbreviation | Node Name | Sector Abbreviation | Sector Name | Up Sequence |
| RS | COAL | Coal resource | SECT1 | Sector | 1 |
| RS | OIL | Oil resource | SECT1 | Sector | 2 |
| PR | CBOIL | Coal Boiler | SECT1 | Sector | 3 |
| PR | OBOIL | Oil Boiler | SECT1 | Sector | 4 |
| AL | AL | Allocation Node | SECT1 | Sector | 5 |

| Down Pass Sequence | | | | | |
|--------------------|-------------------|-----------------|---------------------|-------------|---------------|
| Node Type | Node Abbreviation | Node Name | Sector Abbreviation | Sector Name | Down Sequence |
| DE | STDEM | Steam demand | SECT1 | Sector | 1 |
| AL | AL | Allocation Node | SECT1 | Sector | 2 |
| PR | CBOIL | Coal Boiler | SECT1 | Sector | 3 |
| PR | OBOIL | Oil Boiler | SECT1 | Sector | 4 |



Convergence Parameter Specifications

Run Parameters

Output Codes

Non-electric Units

Electric Units

Convergence Parameters:

Relative Tolerance: (Fraction)

Absolute Tolerance: (kBOE)

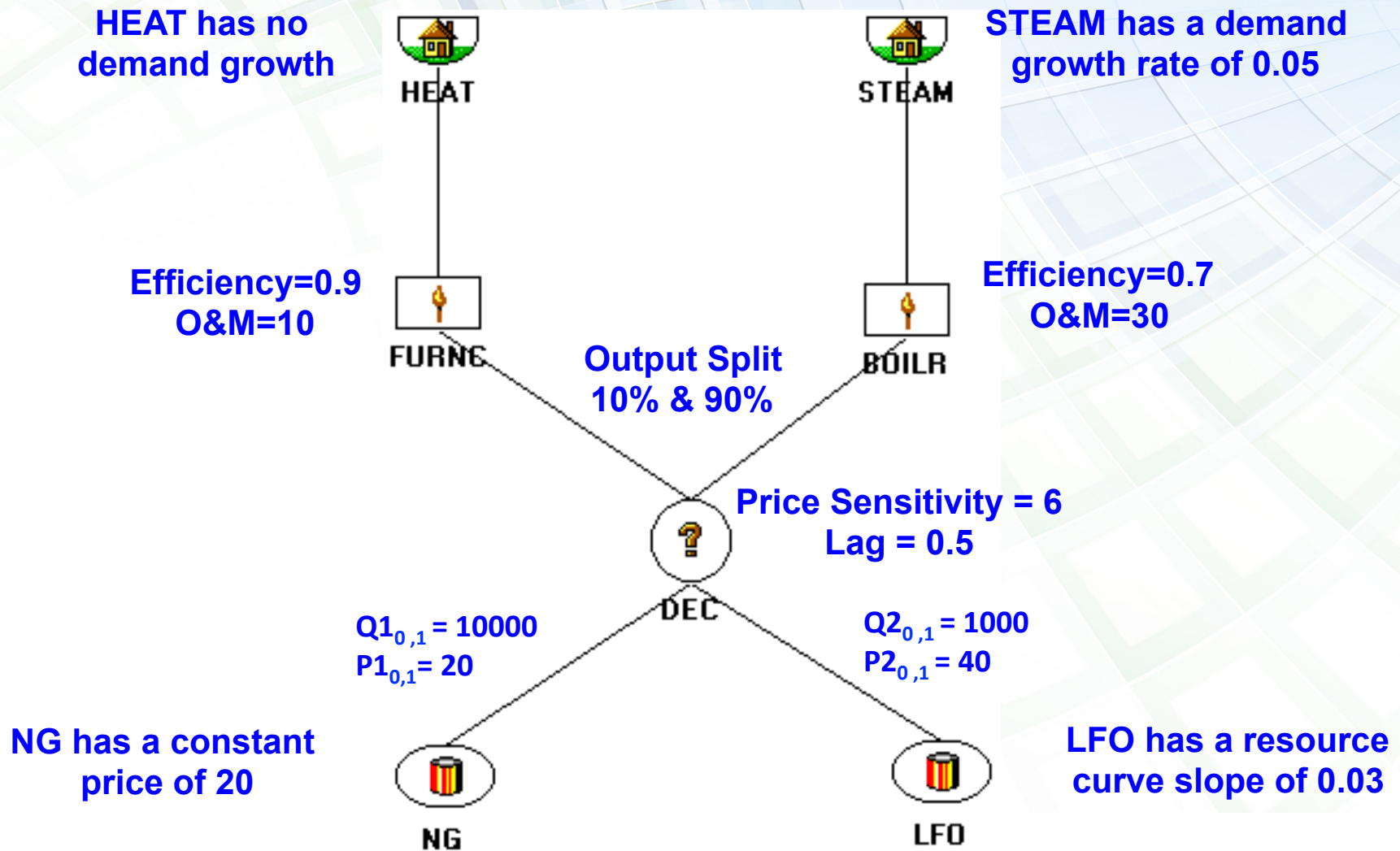
Maximum Iterations: (1-100)

Lower Bound Relaxation Range:

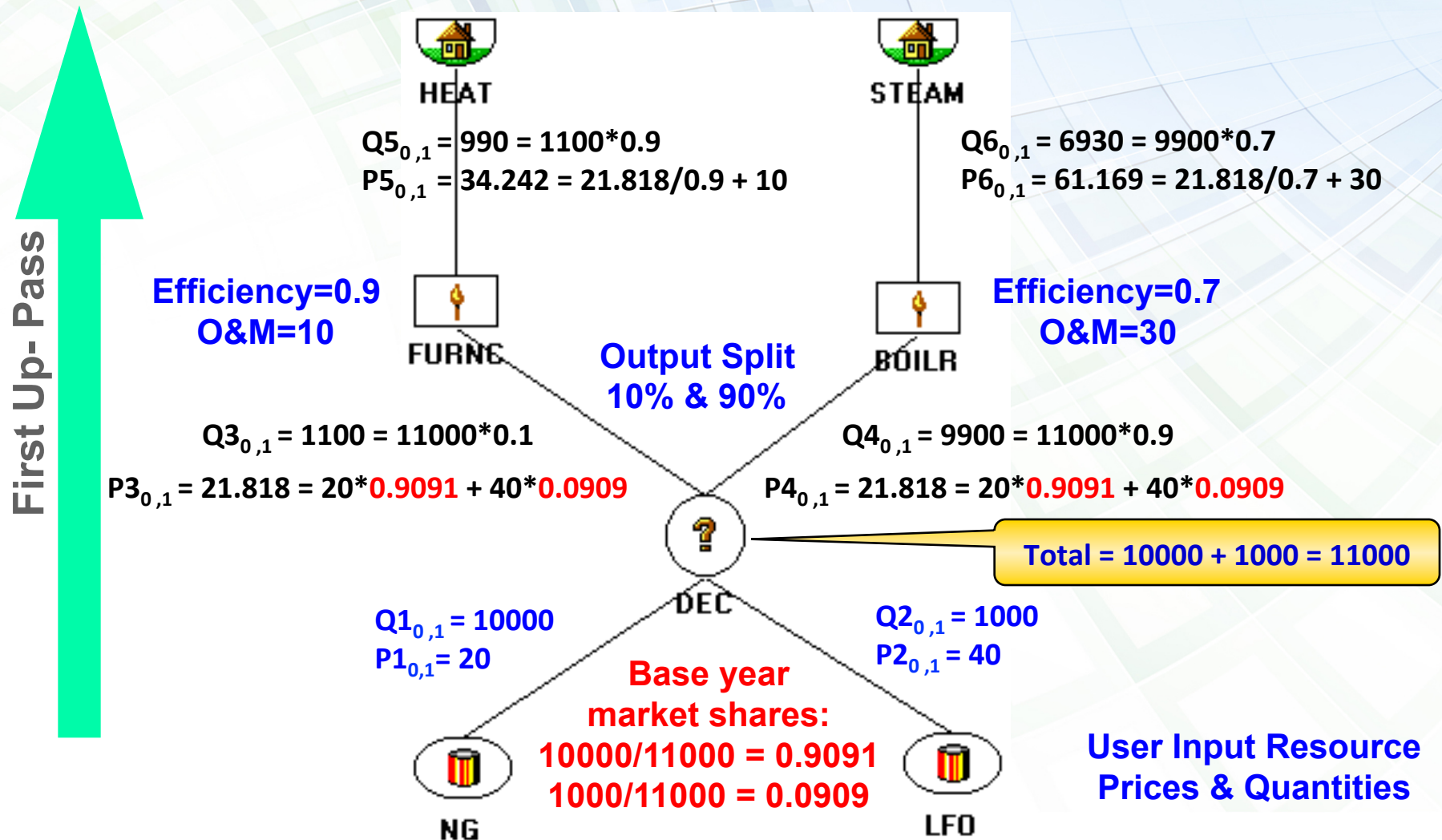
Upper Bound Relaxation Range:



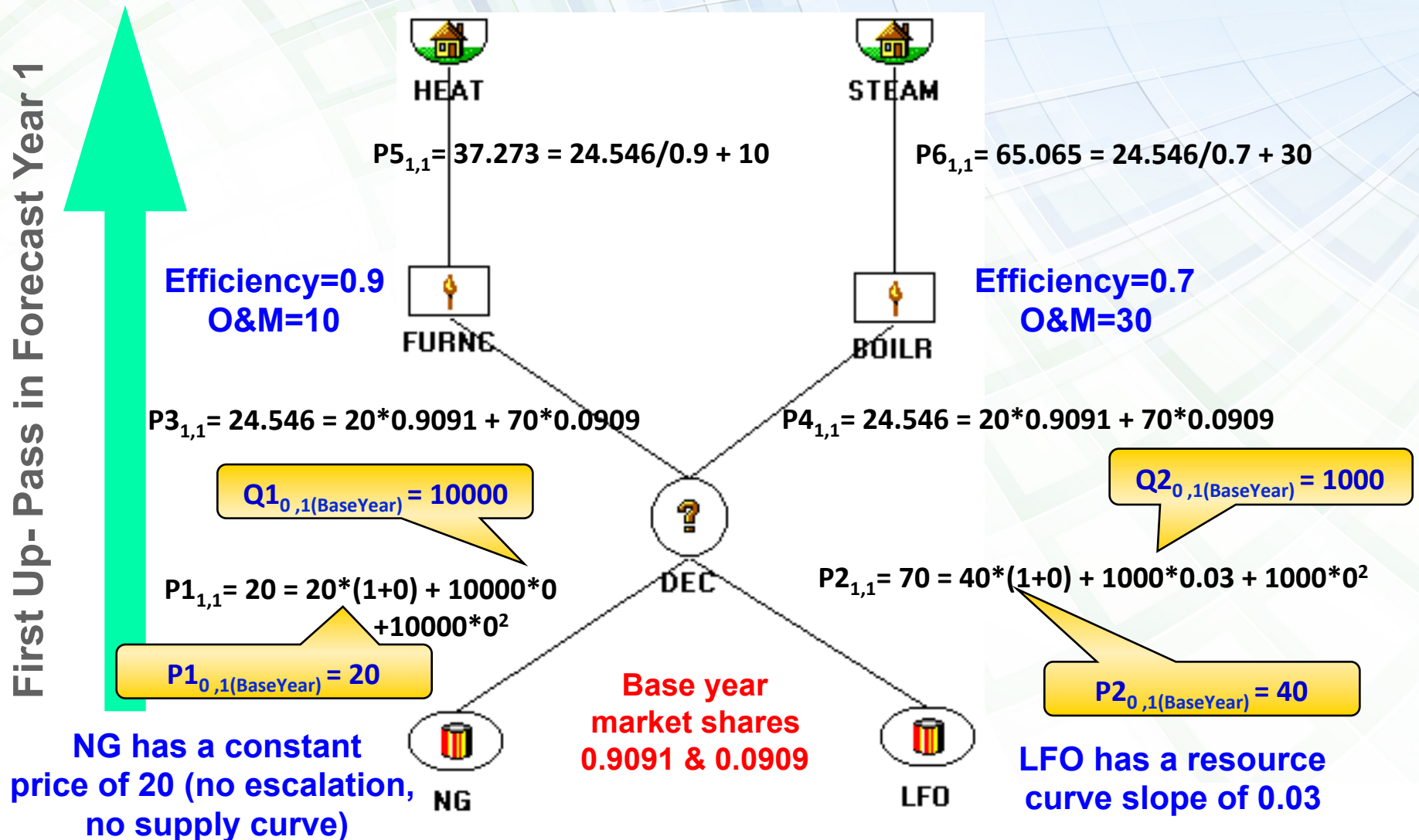
User-input Data for the Network (Base Year Values)



BASE YEAR: The **First Up-Pass** Is Performed to Determine **Base Year Prices and Quantities** on Every Network Link



YEAR 1, ITERATION 1: The *First Up-Pass* Is Performed to Determine Prices for the *First Forecast Year*



YEAR 1, ITERATION 1: The **First Down-Pass** Is Performed to Make an Initial Guess For Quantities For **First Forecast Year**

First Down - Pass in Forecast Year 1

HEAT has no demand growth



HEAT

$$Q_{5,1,1} = 990 = 990 * (1+0)$$

$$Q_{5,0,1(\text{BaseYear})} = 990$$

Efficiency=0.9



FURN

$$Q_{3,1,1} = 1100 = 990 / 0.9$$

Total Allocation
11495 = 1100 + 10395

STEAM has a demand growth rate of 0.05



STEAM

$$Q_{6,1,1} = 7276.5 = 6930 * (1+0.05)$$

$$Q_{6,0,1(\text{BaseYear})} = 6930$$

Efficiency=0.7



BOILR

$$Q_{4,1,1} = 10395 = 7276.5 / 0.7$$

Price Sensitivity = 6
Lag = 0.5



DEC

$$Q_{1,1,1} = 10969.4 = 11495 * 0.9543$$

LOGIT:
1st down pass
market shares
0.9543 & 0.0457



NG

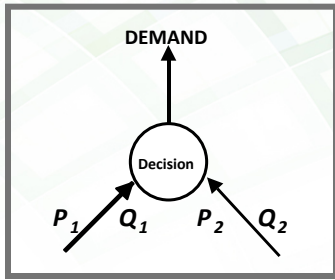


LFO

$$Q_{2,1,1} = 525.6 = 11495 * 0.0457$$

Market shares
are based on 1st
up-pass prices
(next slide...)

YEAR 1, ITERATION 1: Market Share Calculation



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

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

Initial market shares

$$MSL_{1,1} = 0.999 = \frac{\left[\frac{1}{20} \right]^6}{\left[\frac{1}{70} \right]^6 + \left[\frac{1}{20} \right]^6}$$

g = 6

$$MSL_{2,1} = 0.001 = \frac{\left[\frac{1}{70} \right]^6}{\left[\frac{1}{70} \right]^6 + \left[\frac{1}{20} \right]^6}$$

Price from 1st year in 1st up-pass

Market Shares are Adjusted for System Lags Using Lag Equation

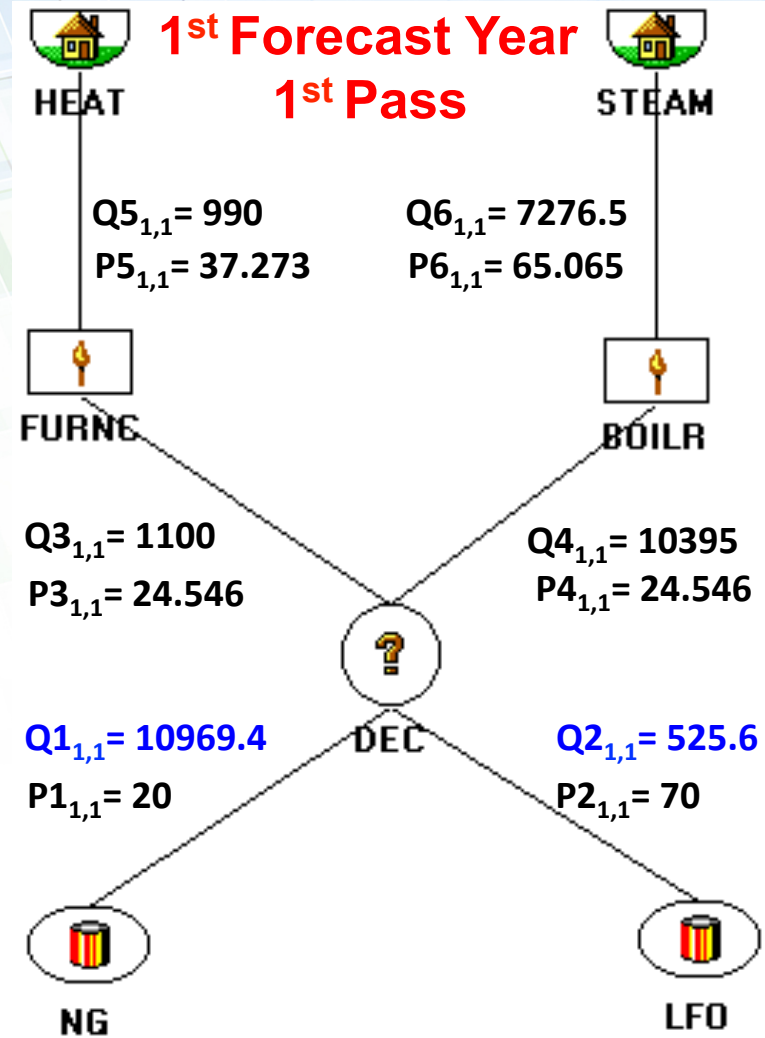
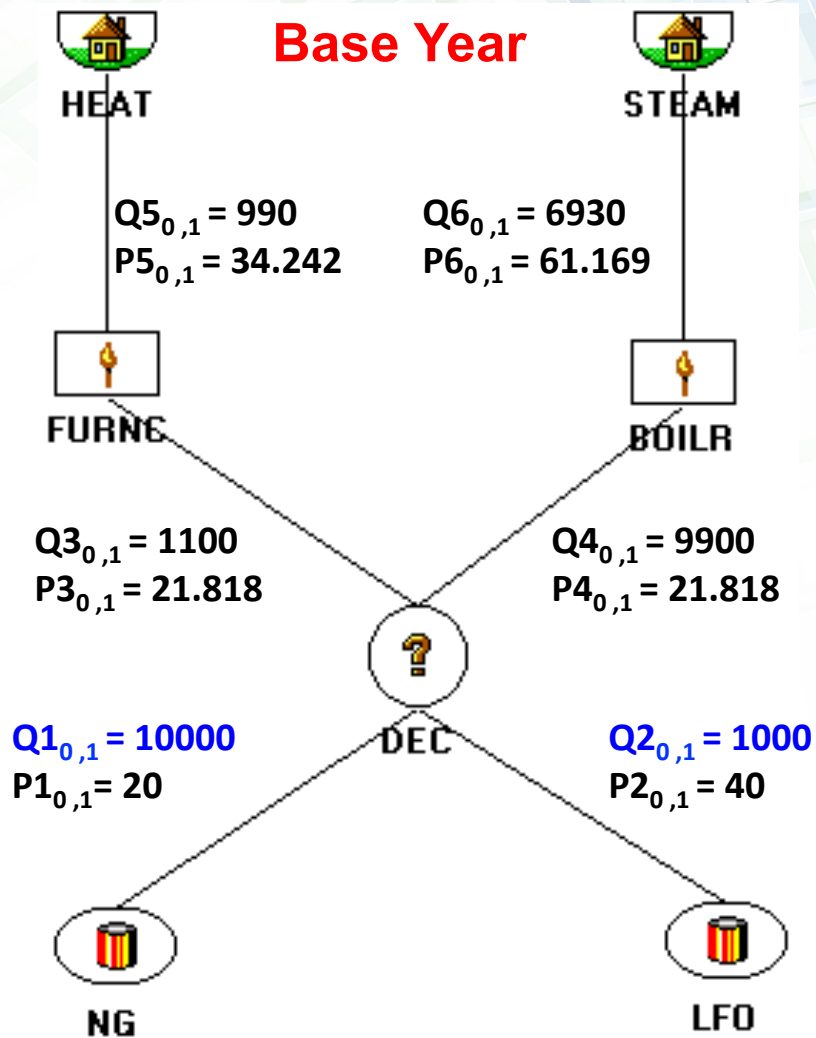
$$MSL_{1,1} = 0.9543 = 0.90909 + ((0.999 - 0.90909) * 0.5)$$

$$MSL_{2,1} = 0.0457 = 0.09091 + ((0.001 - 0.09091) * 0.5)$$

Previous (Base Year) Market Shares

Lag = 0.5

YEAR 1, ITERATION 1: Prices and Quantities Have Changed from the Base Year



YEAR 1, ITERATION 1: BALANCE Checks for Convergence After the First Iteration

Convergence report:

$Q1_{0,1} = 10000$ $Q1_{1,1} = 10969.4$ $RERR = 9.7 \%$ $ABERR = +969.4$
 $Q2_{0,1} = 1000$ $Q2_{1,1} = 525.6$ $RERR = -47.4 \%$ $ABERR = -474.4$

Errors are relative
to the base year (the quantity used to
estimate the prices in Year 1 first up-
pass)

Errors exceed both
convergence criteria
of 1% and 1 kBOE

BALANCE makes quantity adjustments for the 2nd up pass:

$$Q1_{1,1,adj} = 10484.7 = (Q1_{0,1} + Q1_{1,1}) / 2 \\ = (10000 + 10969.4) / 2$$

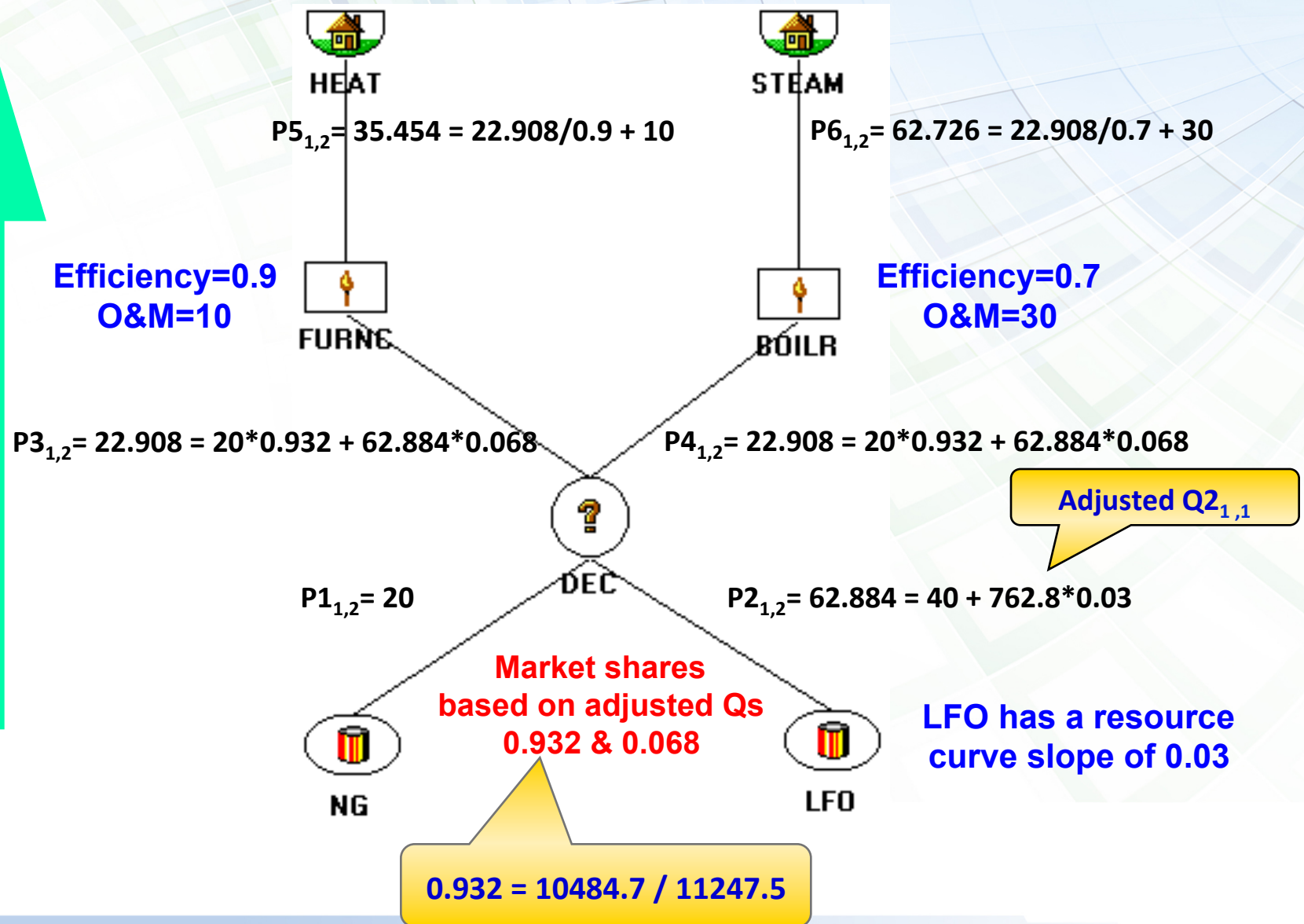
$$Q2_{1,1,adj} = 762.8 = (Q2_{0,1} + Q2_{1,1}) / 2 \\ = (1000 + 525.6) / 2$$

As a 2nd guess,
an average is used

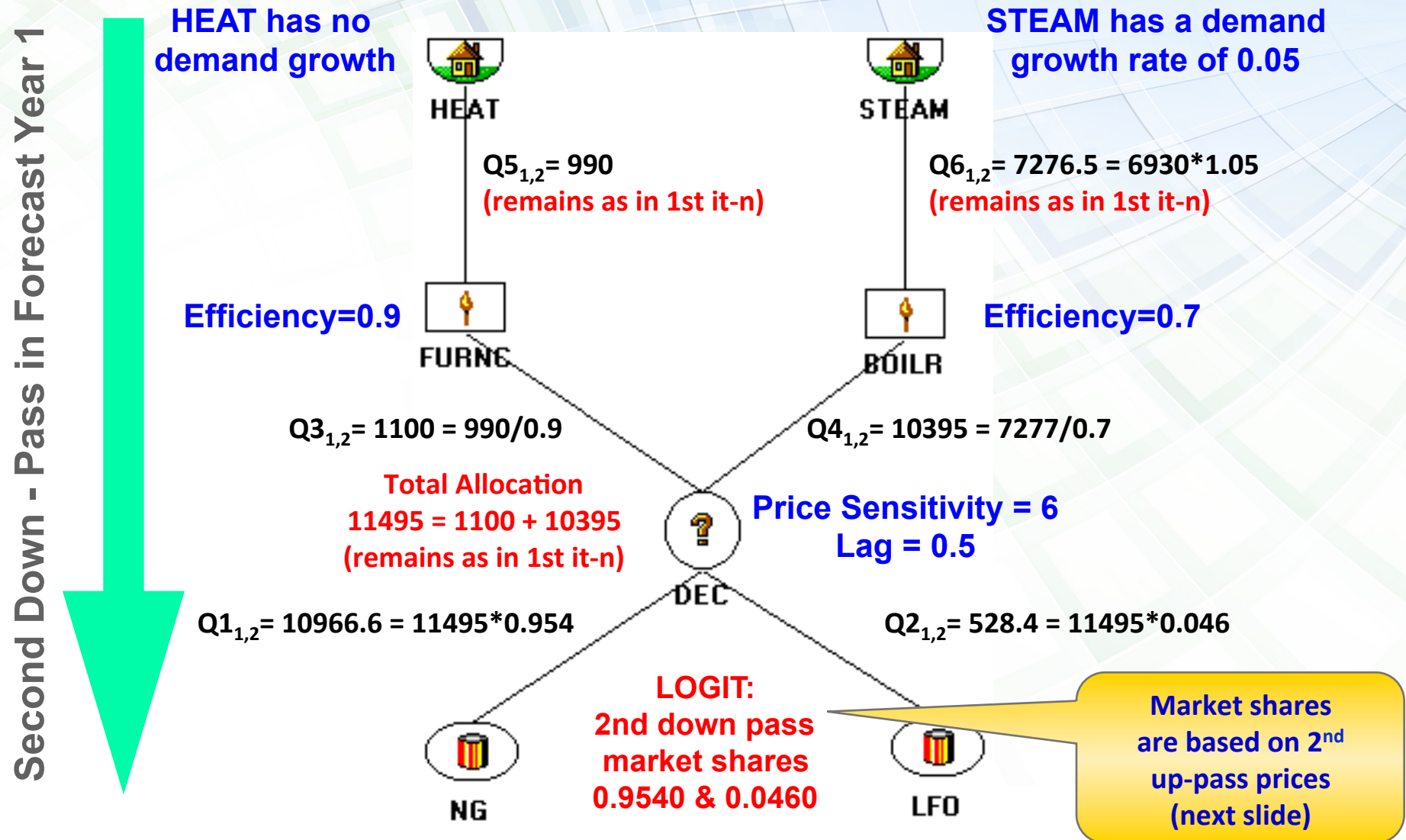


YEAR 1, ITERATION 2: A *Second Up-Pass* Is Performed for the *First Forecast Year*

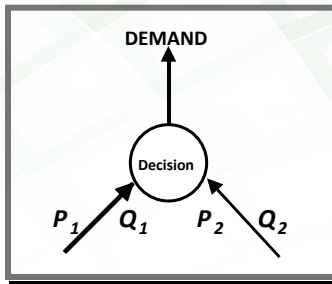
Second Up- Pass in Forecast Year 1



YEAR 1, ITERATION 2: A **Second Down-Pass** Is Performed to Re-compute Quantities for the **First Forecast Year**



YEAR 1, ITERATION 2: Market Share Calculation



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

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

Initial market shares

$$MSL_{1,1} = 0.9989 = \frac{\left[\frac{1}{20} \right]^6}{\left[\frac{1}{62.9} \right]^6 + \left[\frac{1}{20} \right]^6}$$

Slight change from 1st iter-n

$g = 6$

$$MSL_{2,1} = 0.001 = \frac{\left[\frac{1}{62.9} \right]^6}{\left[\frac{1}{62.9} \right]^6 + \left[\frac{1}{20} \right]^6}$$

Price from 1st year in 2nd up-pass

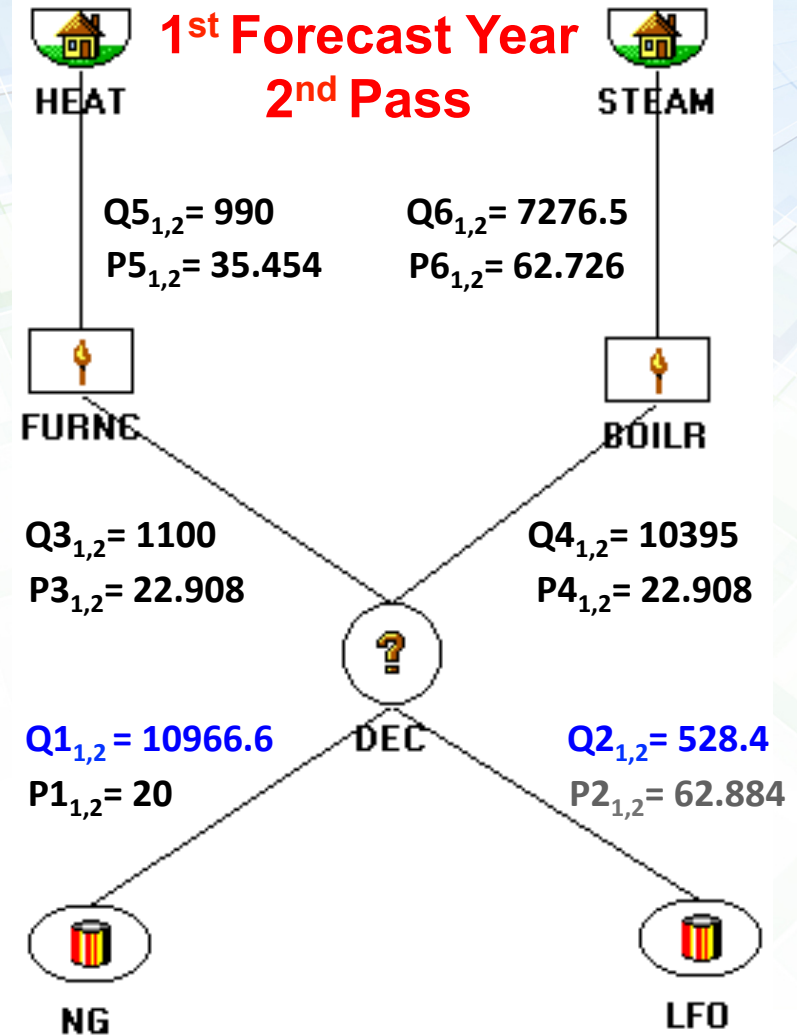
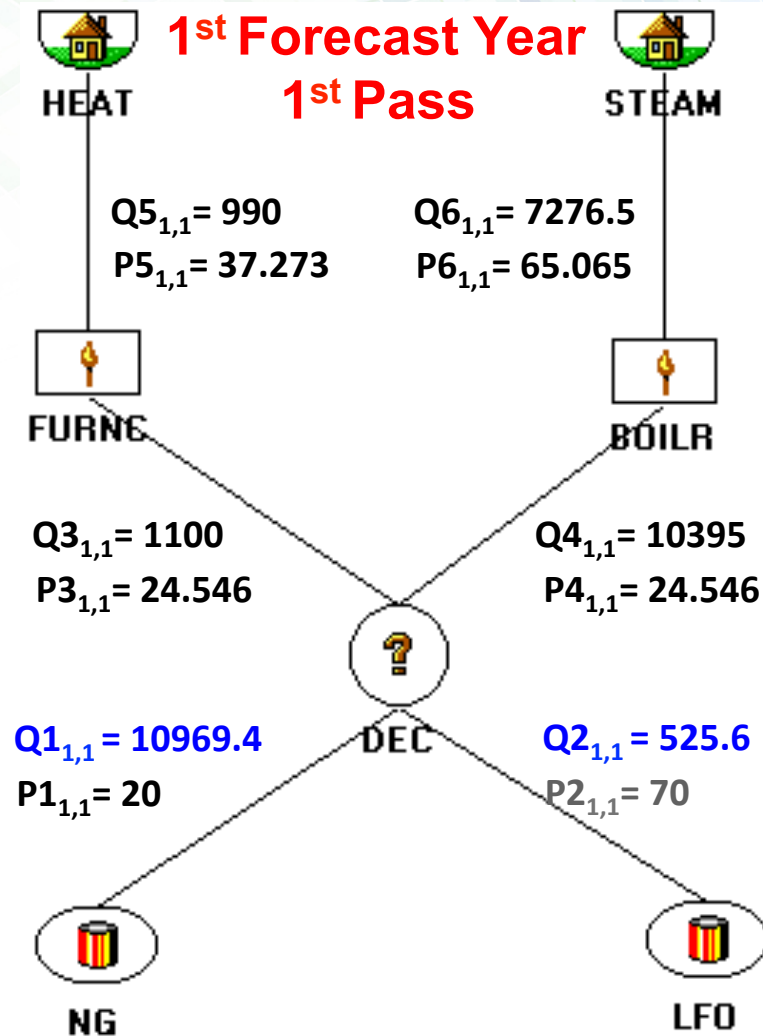
Market Shares are Adjusted for System Lags Using Lag Equation

$$MSL_{1,1} = 0.9540 = 0.90909 + ((0.9989 - 0.90909) * 0.5)$$

$$MSL_{2,1} = 0.0460 = 0.09091 + ((0.001 - 0.09091) * 0.5)$$

Lag = 0.5

YEAR 1, ITERATION 2: Prices and Quantities Have Changed from the First Pass



YEAR 1, ITERATION 2: BALANCE Checks for Convergence after the Second Iteration

Convergence report:

Errors exceed both convergence criteria of 1% and 1 kBOE but are smaller than in the 1st pass

$$\begin{array}{llll} Q_{1,1,\text{adj}} = 10484.7 & Q_{1,2} = 10966.6 & \text{RERR} = 4.6 \% & \text{ABERR} = 481.9 \\ Q_{2,1,\text{adj}} = 762.8 & Q_{2,2} = 528.4 & \text{RERR} = -30.7 \% & \text{ABERR} = -234.4 \end{array}$$

Errors are relative to the 1st pass adjusted quantities (the quantity used to estimate the prices in the up-pass)

BALANCE makes quantity adjustments for the 3rd up pass:

$$\begin{aligned} Q_{1,2,\text{adj}} &= 10918.4 = (Q_{1,1} * 0.1) + (Q_{1,2} * 0.9) \\ &= (10484.7 * 0.1) + (10966.6 * 0.9) \end{aligned}$$

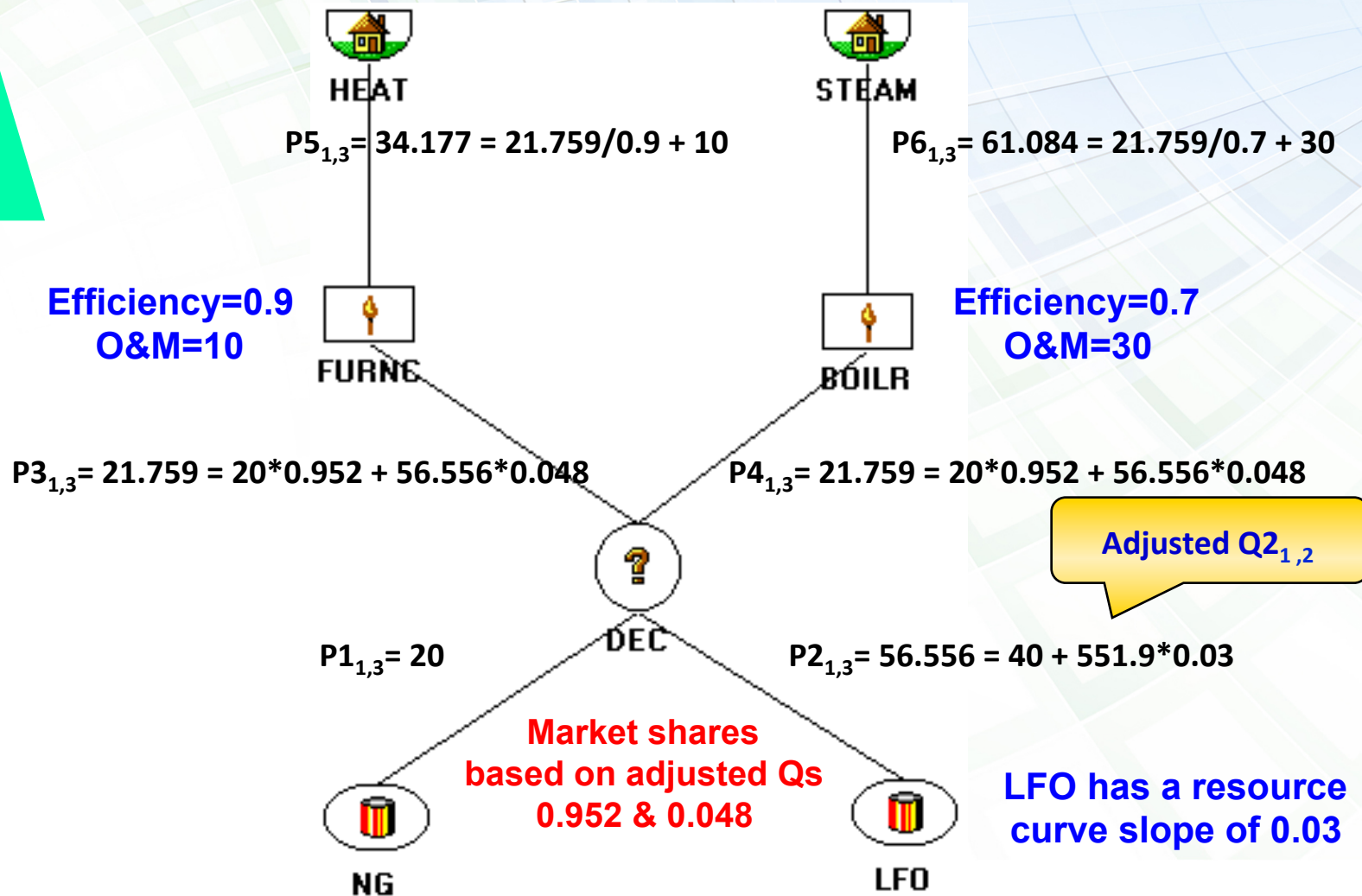
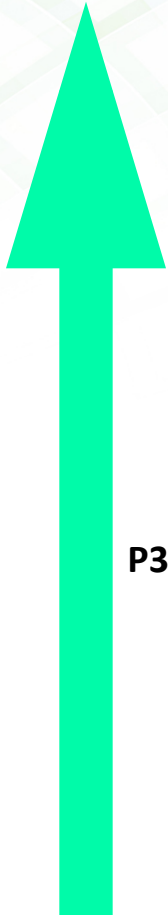
$$\begin{aligned} Q_{2,2,\text{adj}} &= 551.9 = (Q_{2,1} * 0.1) + (Q_{2,2} * 0.9) \\ &= (762.8 * 0.1) + (528.4 * 0.9) \end{aligned}$$

Lower relaxation

Upper relaxation

YEAR 1, ITERATION 3: A *Third Up-Pass* Is Performed for the *First Forecast Year*

Third Up- Pass in Forecast Year 1



YEAR 1, ITERATION 3: A *Third Down-Pass* Is Performed to Re-compute Quantities for the *First Forecast Year*

Third Down - Pass in Forecast Year 1

HEAT has no demand growth



HEAT

$$Q5_{1,3} = 990$$

(remains as in 1st it-n)

STEAM has a demand growth rate of 0.05



STEAM

$$Q6_{1,3} = 7276.5 = 6930 * 1.05$$

(remains as in 1st it-n)

Efficiency=0.9



FURNCE

$$Q3_{1,3} = 1100 = 990 / 0.9$$

Total Allocation
 $11495 = 1100 + 10395$
(remains as in 1st it-n)

Efficiency=0.7



BOILR

$$Q4_{1,3} = 10395 = 7277 / 0.7$$

Price Sensitivity = 6
Lag = 0.5



DEC

$$Q1_{1,3} = 10961.3 = 11495 * 0.9536$$

LOGIT:
3rd down pass market shares
0.9536 & 0.0464

$$Q2_{1,3} = 533.7 = 11495 * 0.0464$$



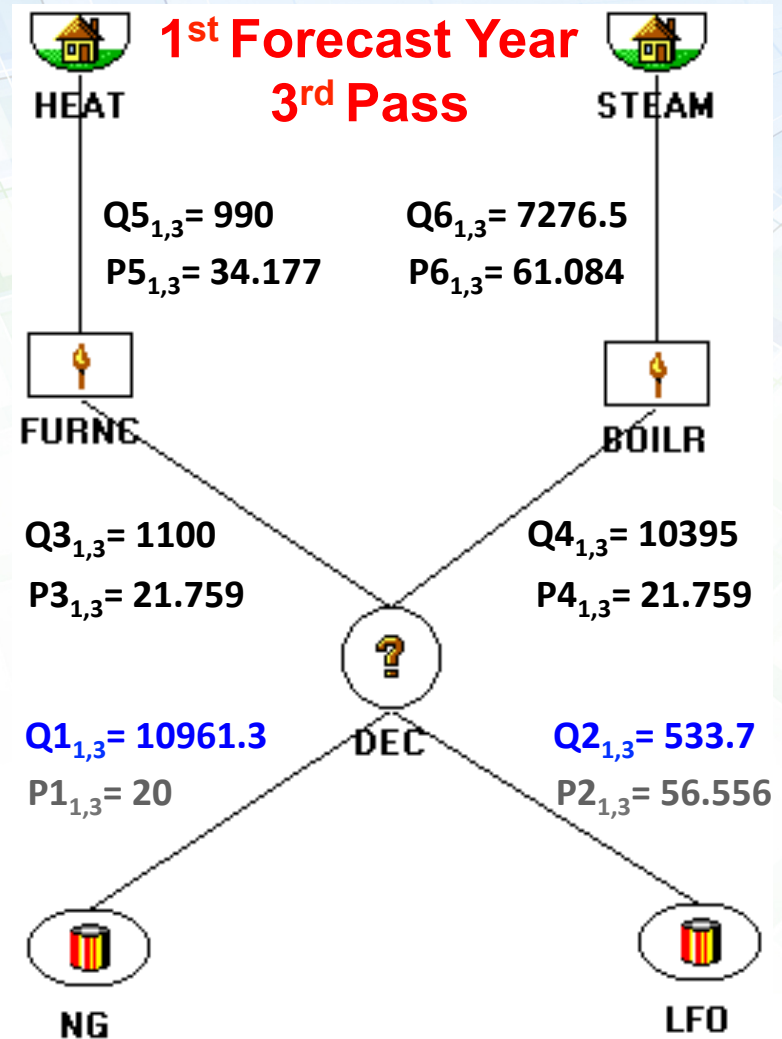
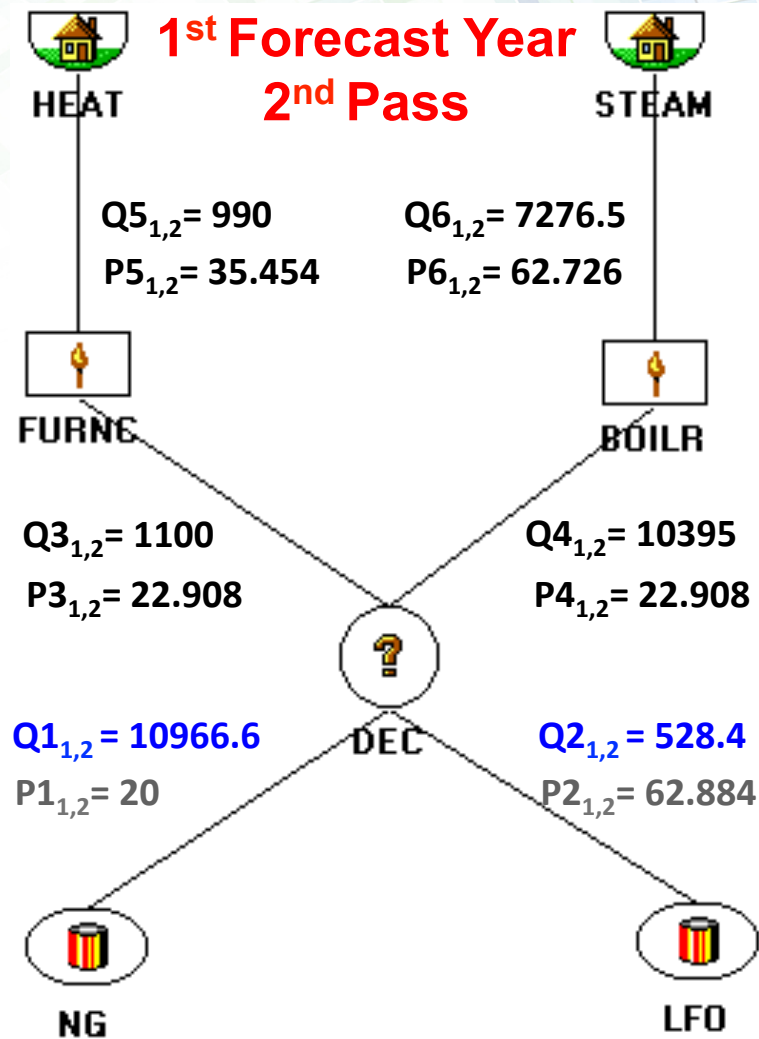
NG



LFO

Market shares are based on 3rd up-pass prices

YEAR 1, ITERATION 3: Prices and Quantities Have Changed from the Second Pass



YEAR 1, ITERATION 3: BALANCE Checks for Convergence after the Third Iteration

Convergence report:

Errors for at least one resource exceed both convergence criteria of 1% and 1 kBOE but are smaller than in the 2nd pass

$$\begin{array}{llll} Q1_{1,2,adj} = 10918.4 & Q1_{1,3} = 10961.3 & RERR = 0.4 \% & ABERR = 42.9 \\ Q2_{1,2,adj} = 551.9 & Q2_{1,3} = 533.7 & ERROR = -3.2 \% & ABERR = -18.2 \end{array}$$

Errors are relative to the 2nd pass adjusted quantities

BALANCE makes quantity adjustments for the 3rd up pass:

$$\begin{aligned} Q1_{1,3,adj} &= 10957.0 = (Q1_{1,2} * 0.1) + (Q1_{1,3} * 0.9) \\ &= (10918.4 * 0.1) + (10961.3 * 0.9) \end{aligned}$$

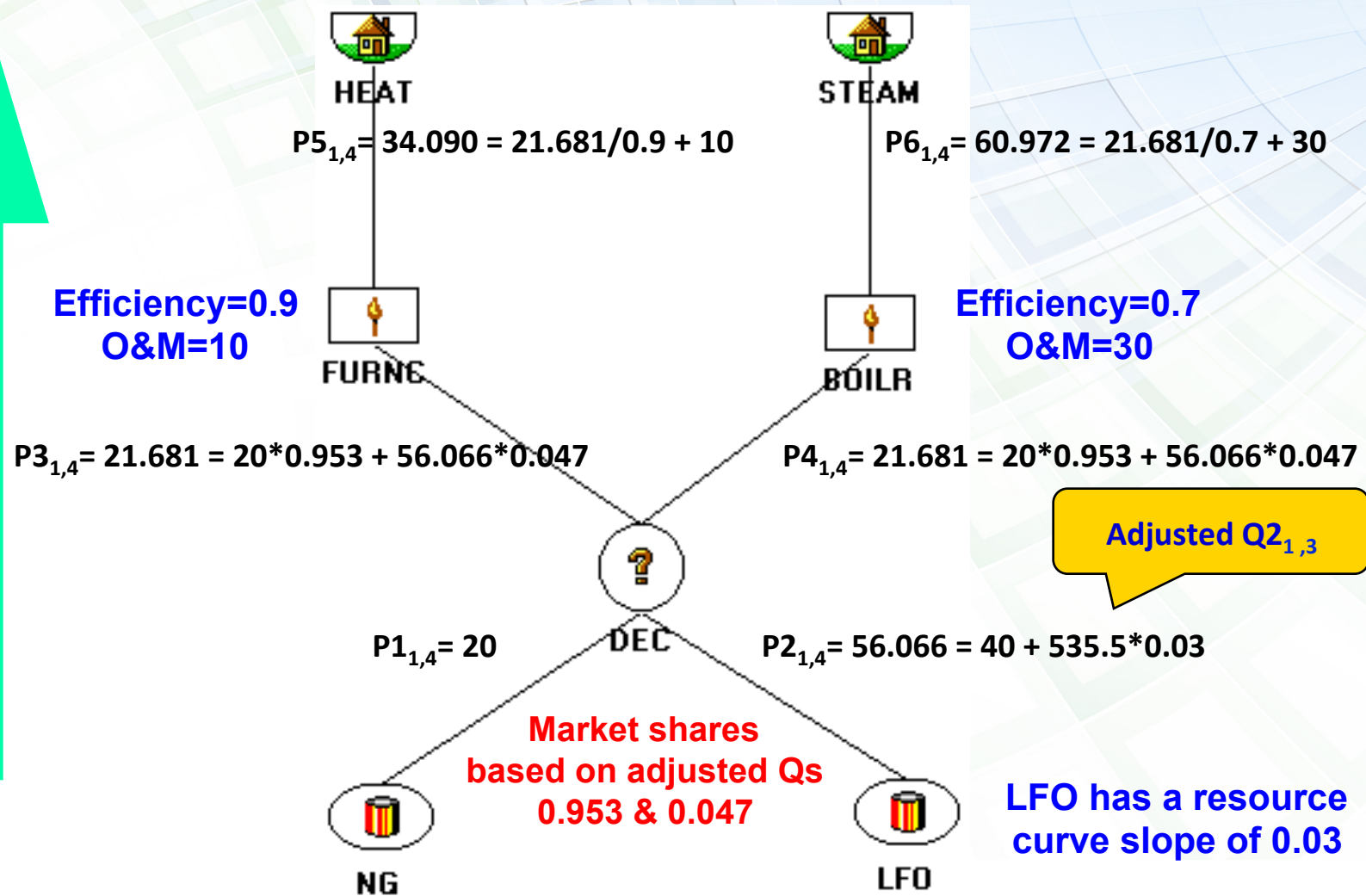
$$\begin{aligned} Q2_{1,3,adj} &= 535.5 = (Q2_{1,2} * 0.1) + (Q2_{1,3} * 0.9) \\ &= (551.9 * 0.1) + (533.7 * 0.9) \end{aligned}$$

Lower relaxation

Upper relaxation

YEAR 1, ITERATION 4: A *Fourth Up-Pass* Is Performed for the *First Forecast Year*

Fourth Up- Pass in Forecast Year 1



YEAR 1, ITERATION 4: A **Fourth Down-Pass** Is Performed to Re-compute Quantities for the **First Forecast Year**

Fourth Down - Pass in Forecast Year 1

HEAT has no demand growth



HEAT

$$Q5_{1,4} = 990$$

Efficiency=0.9



FURNCE

$$Q3_{1,4} = 1100 = 990 / 0.9$$

Total Allocation
 $11495 = 1100 + 10395$

STEAM has a demand growth rate of 0.05



STEAM

$$Q6_{1,4} = 7276.5 = 6930 * 1.05$$

Efficiency=0.7



BOILER

$$Q4_{1,4} = 10395 = 7277 / 0.7$$

Price Sensitivity = 6
Lag = 0.5



DEC

$$Q1_{1,4} = 10960.7 = 11495 * 0.9535$$

$$Q2_{1,4} = 534.3 = 11495 * 0.0465$$

LOGIT:

4th down pass market shares
0.9535 & 0.0465



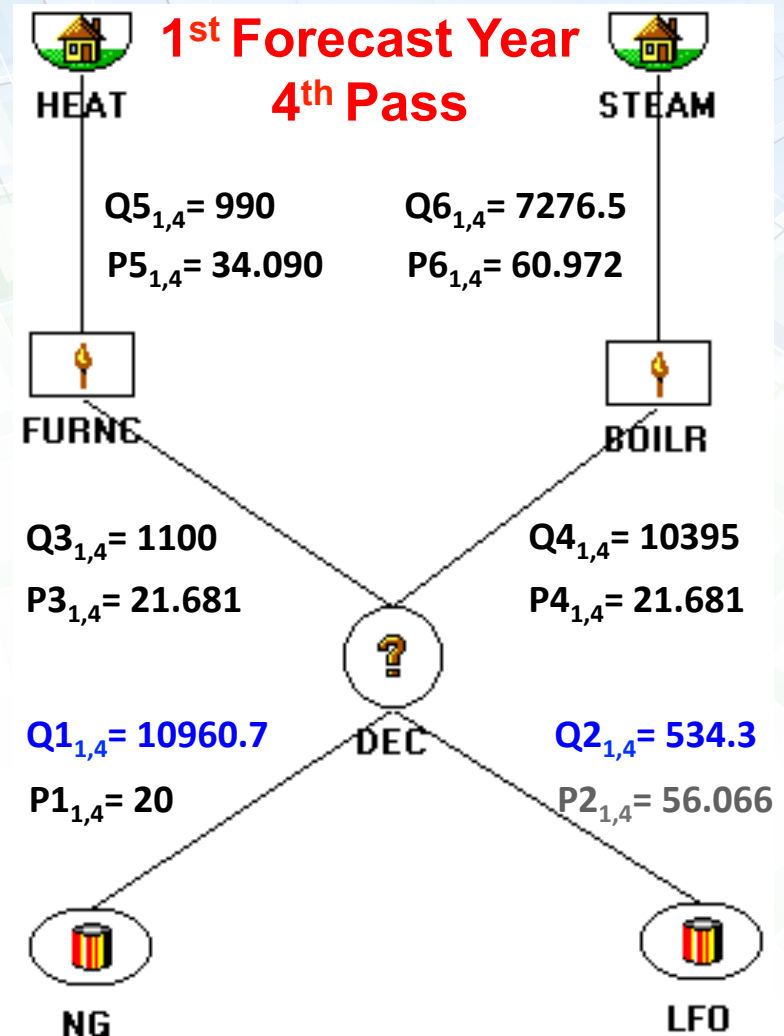
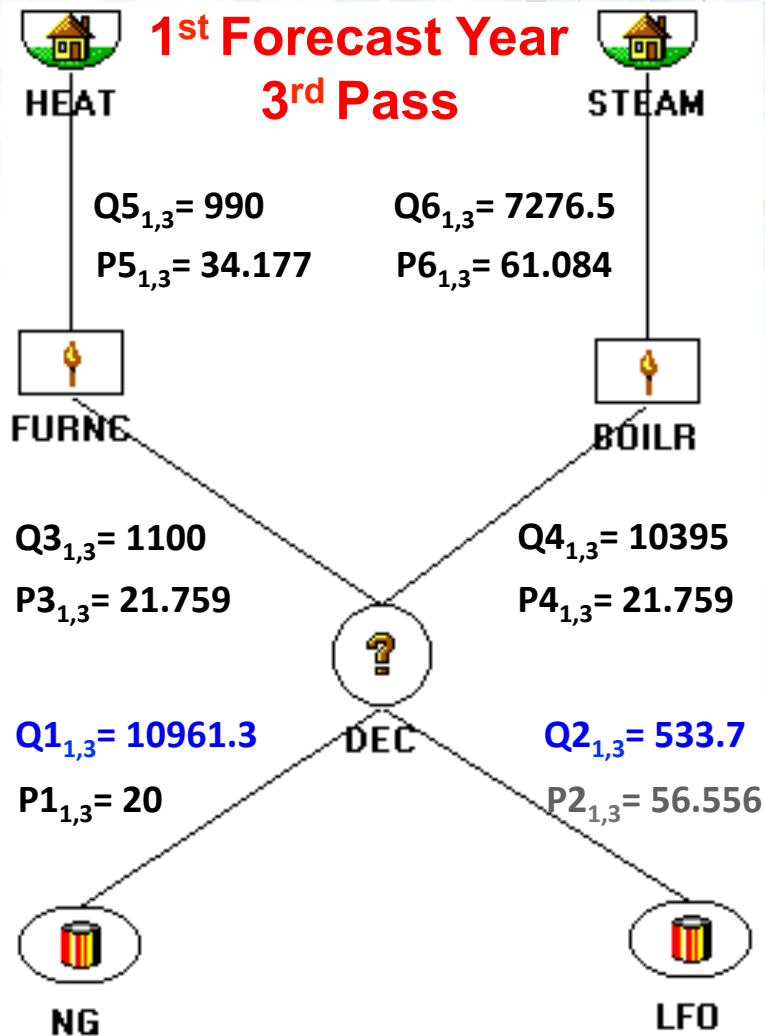
NG



LFO

Market shares are based on 4th up-pass prices

YEAR 1, ITERATION 4: Quantities Have Converged but Prices Changed from the Third Pass



YEAR 1, ITERATION 4: BALANCE Checks for Convergence after the Third Iteration

Convergence report:

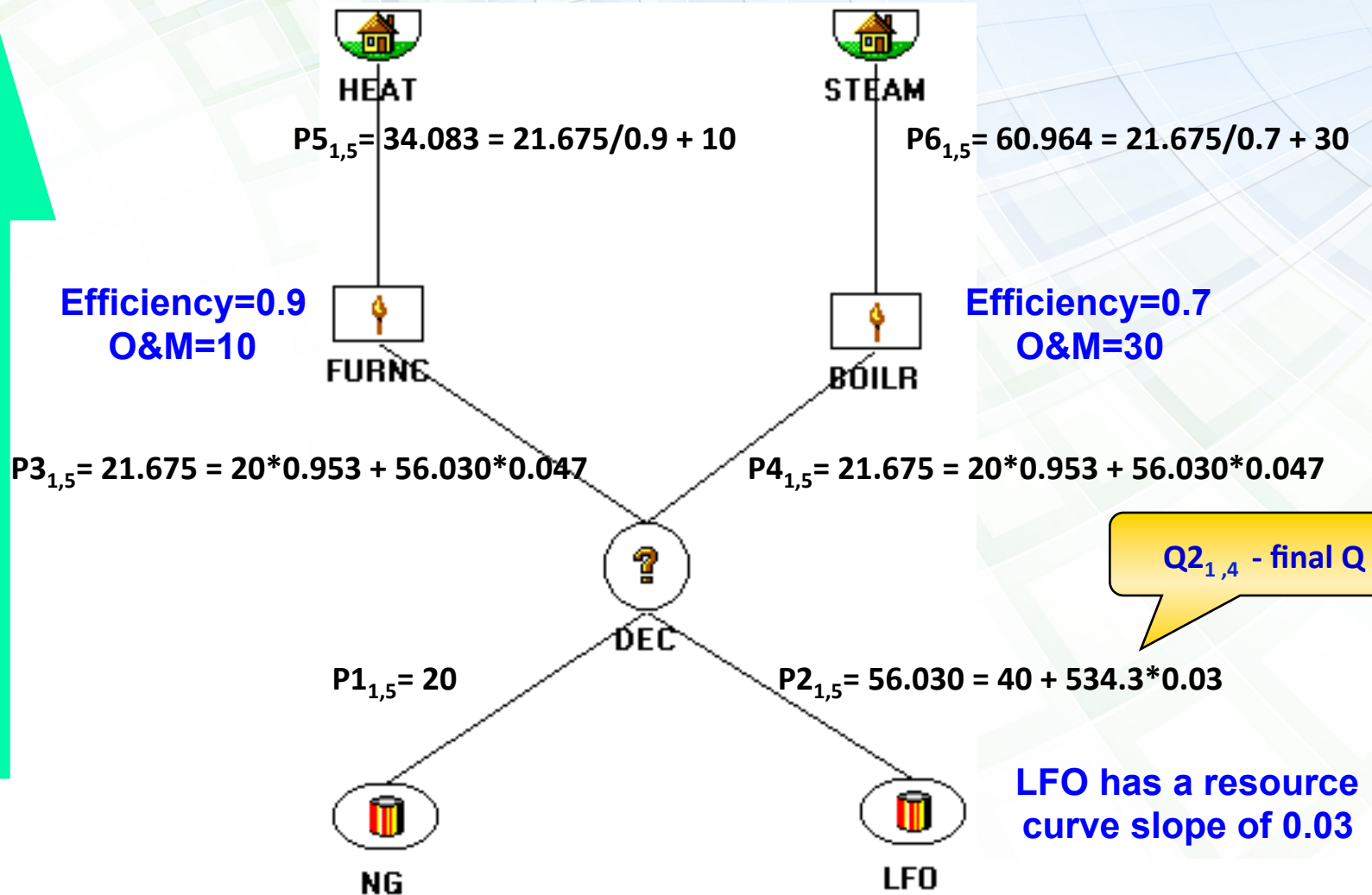
$Q1_{1,3,adj} = 10957.0$ $Q1_{1,4} = 10960.7$ $RERR = 0.03\%$ $ABERR = 3.7$
 $Q2_{1,3,adj} = 535.5$ $Q2_{1,4} = 534.3$ $ERROR = -0.2\%$ $ABERR = -1.2$

Errors are relative
to the 3rd pass
adjusted quantities

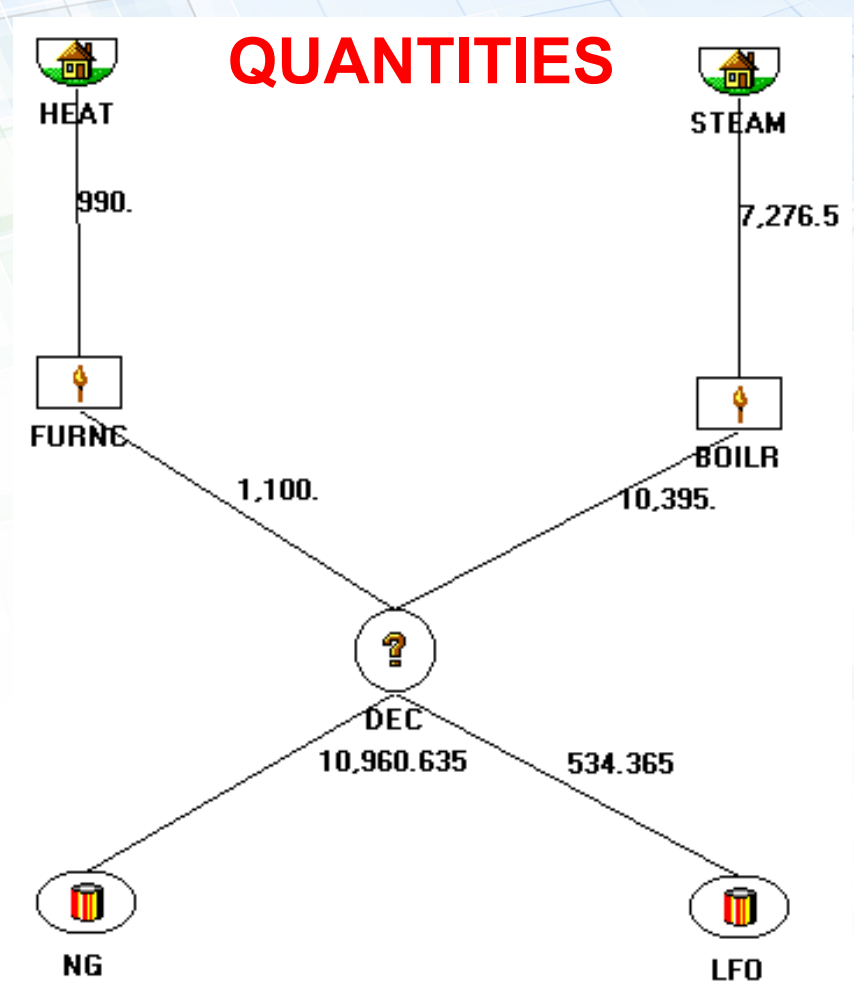
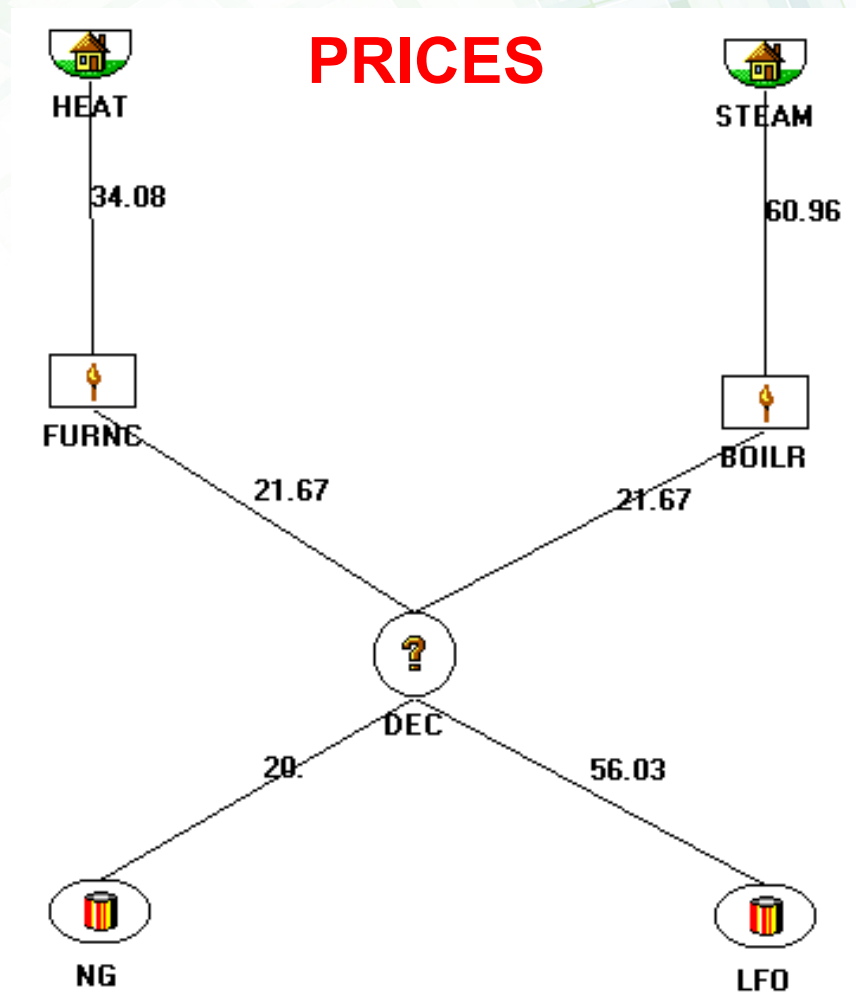
Errors on all resources meet at least
one convergence criteria, in this
case, the relative convergence
criteria of 1%

YEAR 1, ITERATION 4: After Convergence, One **Last Up-Pass** is Performed to Compute Final Energy Prices

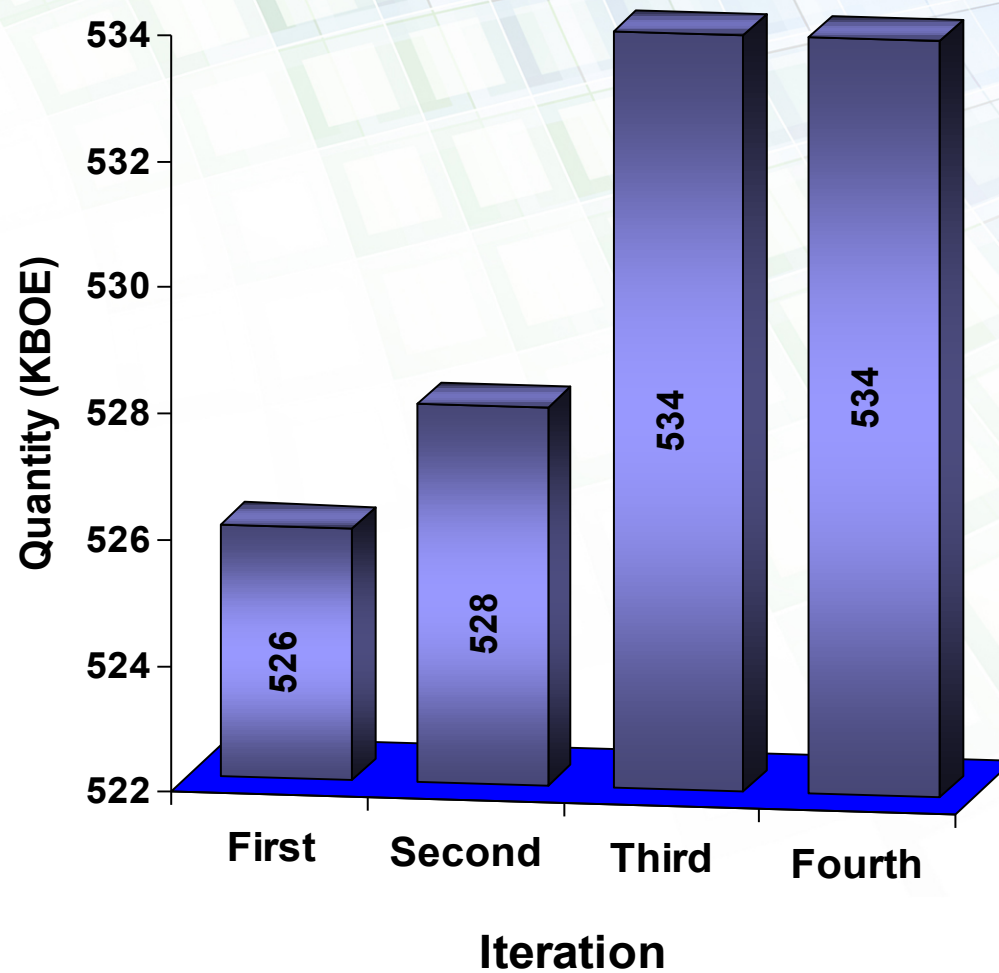
Fifth Up-Pass in Forecast Year 1



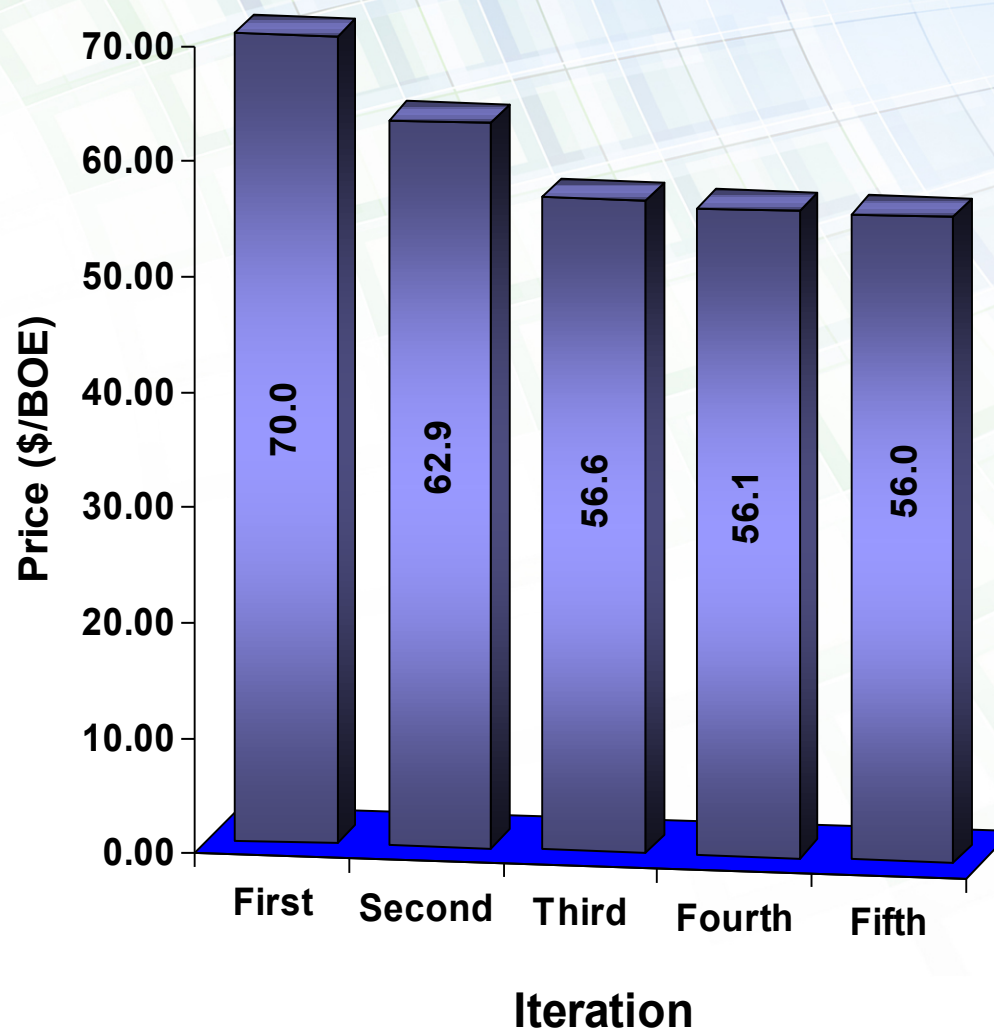
Year 1: Network Results for *First Forecast Year*



Evolution of Energy Quantities on Link 2



Evolution of Energy Prices on Link 2

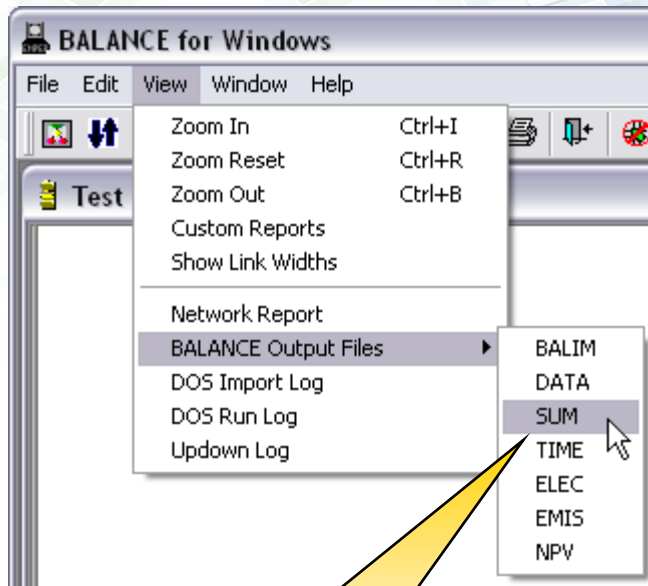


The Simulation Status Folder Displays the Evolution of Quantities

| Simulation Status | | | | | |
|-------------------------------------------|-------------------------------------------------------------------------------|------------------------------------|-----------------|--------------------------------|--|
| The requested simulation run is complete: | | | | | |
| | | Maximum error in terms of fraction | | Maximum error in terms of kBOE | |
| 2008 | ITERATION = 1 | MAX REL ERR = -4.743746e-001 | ABS ERR = 474.4 | # | |
| 2008 | ITERATION = 2 | MAX REL ERR = -3.072444e-001 | ABS ERR = 234.4 | # | |
| 2008 | ITERATION = 3 | MAX REL ERR = -3.290778e-002 | ABS ERR = 18.2 | # | |
| 2008 | ITERATION = 4 | MAX REL ERR = -2.269972e-003 | ABS ERR = 18.2 | # | |
| 2008 | CONVERGENCE AT REL. TOL. = 0.010000 AND ABS. TOL. = 1.0 AFTER 4 ITERATIONS. # | | | | |
| 2009 | ITERATION = 1 | MAX REL ERR = -4.734077e-001 | ABS ERR = 253.5 | # | |
| 2009 | ITERATION = 2 | MAX REL ERR = -3.075564e-001 | ABS ERR = 125.7 | # | |
| 2009 | ITERATION = 3 | MAX REL ERR = -3.794662e-002 | ABS ERR = 11.2 | # | |
| 2009 | ITERATION = 4 | MAX REL ERR = -3.416705e-003 | ABS ERR = 11.2 | # | |
| 2009 | CONVERGENCE AT REL. TOL. = 0.010000 AND ABS. TOL. = 1.0 AFTER 4 ITERATIONS. # | | | | |
| 2010 | ITERATION = 1 | MAX REL ERR = -4.698272e-001 | ABS ERR = 134.1 | # | |
| 2010 | ITERATION = 2 | MAX REL ERR = -3.048807e-001 | ABS ERR = 66.6 | # | |
| 2010 | ITERATION = 3 | MAX REL ERR = -3.876605e-002 | ABS ERR = 6.1 | # | |



Detailed Results of the Iterations Can be Found in the *BALANCE SUM.out* File



SU000095.TXT - Notepad

File Edit Format View Help

SIMULATION RUN ON: Sat Dec 09 11:27:35 2006
Baseyear: 1999 Number of Years: 20

Quantities are in TJ and Prices are in \$/GJ

ITERATION NO. 1 YEAR 1999

UP-PASS :

| | | | | | | | | |
|----|----|---------------|------|-------|------|------|----|-----------|
| P | RS | Coal (Sect1) | LINK | ln2 | YEAR | 1999 | \$ | 1.2900 |
| P | RN | Solar (Sect1) | LINK | ln1 | YEAR | 1999 | \$ | 0.0000 |
| P | PR | SHeat (Sect1) | LINK | solar | YEAR | 1999 | \$ | 8.5768 |
| P | PR | CHeat (Sect1) | LINK | coal | YEAR | 1999 | \$ | 4.5857 |
| P | AL | Decis (Sect1) | LINK | ln5 | YEAR | 1999 | \$ | 4.8737 |
| QB | AL | Decis (Sect1) | LINK | ln5 | YEAR | 1999 | | 14098.837 |

ITERATION NO. 1 YEAR 2000

UP-PASS :

| | | | | | | | | |
|---|----|---------------|------|-------|------|------|----|--------|
| P | RS | Coal (Sect1) | LINK | ln2 | YEAR | 2000 | \$ | 1.3287 |
| P | RN | Solar (Sect1) | LINK | ln1 | YEAR | 2000 | \$ | 0.0000 |
| P | PR | SHeat (Sect1) | LINK | solar | YEAR | 2000 | \$ | 8.5768 |
| P | PR | CHeat (Sect1) | LINK | coal | YEAR | 2000 | \$ | 4.6373 |
| P | AL | Decis (Sect1) | LINK | ln5 | YEAR | 2000 | \$ | 4.9216 |

DOWN-PASS :

| | | | | | | | | |
|---|----|---------------|-----------|-------|------|------|--|-------------------------------|
| Q | DE | Heat (Sect1) | LINK | ln5 | YEAR | 2000 | | 14098.837 |
| | | ALLOCATE= | | | | | | 14098.84 |
| | | MS=0.931 | Q(coal)= | | | | | 13120.87 |
| | | MS=0.069 | Q(solar)= | | | | | 977.97 |
| | | | | | | | | NMS=0.956 OMS=0.928 LAG=0.100 |
| | | | | | | | | MS=0.044 OMS=0.072 LAG=0.100 |
| Q | AL | Decis (Sect1) | LINK | coal | YEAR | 2000 | | 13120.872 |
| Q | AL | Decis (Sect1) | LINK | solar | YEAR | 2000 | | 977.965 |
| Q | PR | SHeat (Sect1) | LINK | ln1 | YEAR | 2000 | | 2794.186 |
| Q | PR | CHeat (Sect1) | LINK | ln2 | YEAR | 2000 | | 17494.496 |

CONVERGENCE REPORT:

| | | | |
|----------|--------------|---------------|--------------------|
| LINK=ln2 | Q= 17441.860 | HQ= 17494.496 | ERROR= 3.0178e-003 |
| LINK=ln1 | Q= 2906.977 | HQ= 2794.186 | ERROR=-3.8800e-002 |

2000 ITERATION= 1 REL TOL= 0.1000 REL ERR MAX=-3.879986e-002

UP-PASS :



You Can Find All SUM.OUT Files Using the Explorer and Notepad or WordPad

Go to the folder with the same name as your database/study

Go to the "Reports" folder

Right-click, and chose "Open With", and then Chose Notepad or WordPad

Open the file "SuXXXXXX.txt" that corresponds to your case; there will be several SuXXXXXX.txt files if your database contains more than one case

| Name | Size | Type | Date |
|--------------|----------|---------------|---------|
| BA000010.TXT | | | |
| BL000010.TXT | | | |
| DA000010.TXT | | | |
| EL000010.TXT | | | |
| EM000010.TXT | 419 KB | Text Document | 11/20/2 |
| NP000010.TXT | 283 KB | Text Document | 11/20/2 |
| SU000010.TXT | 4.404 KB | Text Document | 11/20/2 |
| TI000010.TXT | | Text Document | 11/20/2 |
| UD000010.TXT | | Text Document | 11/20/2 |

