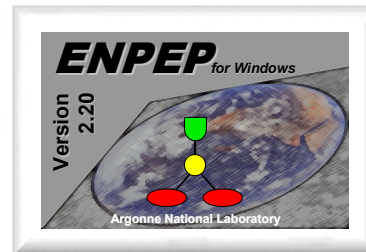


Environmental Calculations in ENPEP-BALANCE

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

In General, there are Several Ways to do an Environmental Analysis

- “Optimize” energy, economics, and environment

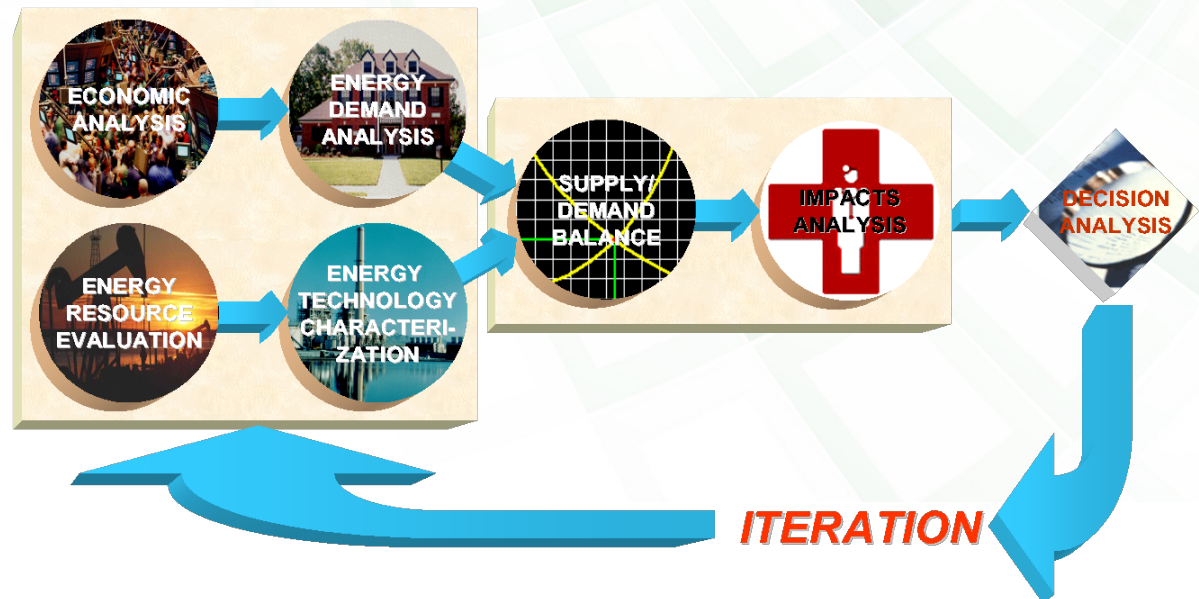
- Very complex
- Results not as transparent
- Too many assumptions (“black box”)

- Maximize environmental “benefit”

- Often too expensive to implement

- Design economic energy system, then iterate to meet environmental requirements

- Resembles decision making process
- Approach used in ENPEP



Main Design Characteristics for Environmental Calculations

- Compute annual levels of atmospheric emissions from energy production, conversion, and consumption
- Implement emissions taxes (e.g., carbon tax) and examine the resulting changes in the energy supply mix and overall emission levels
- Introduce emission control technologies (e.g., electrostatic filters, flue gas desulfurization, DeNox, etc.) and analyze their effect on mitigating pollution levels (++)
 - Compute emissions after control
 - Compute avoided emissions
 - Compute incremental control costs including capital and O&M cost
 - Compute cost-effectiveness of emission controls
 - Update price/cost of output link of process
- Implement emissions limits and examine emissions trading, e.g. cap and trade (++)

(++) **Currently not implemented**



Emissions are Assumed to be a Function of the Following General Parameters

- Level of fuel consumption
- Type of fuel (e.g., coal versus oil versus gas, high sulfur coal versus low sulfur coal)
- Type of combustion technology (steam turbine versus gas turbine, pulverized coal versus stoker furnace, etc.)
- Type of pollution control equipment



ENPEP Uses a Standard Methodology to Determine the Uncontrolled and Controlled Source Emissions



$$\text{Uncontrolled Emissions} = \text{Fuel Consumption} \times \text{Emission Factor} \times \text{Chemical Scale}$$

$$\text{Controlled Emissions} = \text{Uncontrolled Emissions} \times (100 - \text{Control Efficiency}) / 100$$



The Environmental Calculations Can be Activated under Run Parameters

- Checking the “Perform Environmental Calculations” box will activate the environmental routines
- After activating, the user has access to the environmental input data screens as well as the output screens
 - If not activated, the environmental input/output screens are “greyed-out” to indicate they are NOT accessible
- After entering all environmental information and running the case, the user can turn the environmental calculations off again by unchecking this box
 - Speeds up the calculations; useful if BALANCE-energy is not finalized yet
 - Environmental information (inputs and results) is maintained in the database but no calculations are performed
 - Environmental calculations can be turned back on again by re-checking the box

Click to activate
environmental
calculations

Run Parameters	Pollutants	Output Codes	Non-electric Units	Electric Units
Convergence Parameters:				
Relative Tolerance:		0.010	(Fraction)	
Absolute Tolerance:		10.000	(kBOE)	
Maximum Iterations:		11	(1-100)	
Lower Bound Relaxation Range:	0.100			
Upper Bound Relaxation Range:	0.900			
Discount Rate:	10.0		%	
Perform Environmental Calculations: <input checked="" type="checkbox"/>				



The User May Add or Delete Pollutants to the Current Default List

Name	Abbreviation	Chemical Scale
Total Particulate Matter	0PM	Ash
Particulate Matter < 10um	1PM10	Ash
Sulfur Dioxide	2SO2	Sulfur
Nitrogen Oxides	3NOX	
Carbon Monoxide	4CO	
Non-Methane Total Organic Compounds	5NMTO	
Methane	6CH4	
Total Organic Compounds	7TOC	
Carbon Dioxide	8CO2	Carbon
Nitrous Oxides	9N2O	

New Pollutant: Abbr.:

Buttons: OK, Cancel, Add, Delete

Click the **Add** button to insert a new pollutant. The list can include waste generation, wastewater effluents, water consumption, etc.

- **Name** indicates the name of the pollutant
- **Abbreviation** is the 5 character abbreviation for the pollutant
- **Chemical Scale** indicates whether the emissions are considered to be a linear function of a certain fuel characteristic, such as fuel carbon content for CO2 emissions, fuel sulfur content for SO2 emissions, etc.



The User May Specify the Units Used for Environmental Inputs and Outputs

- Environmental units may be specified for both non-electric and electric (if electric sector is used)
- Default Unit** is the unit used internally by the model
- The pull-down menu under **Unit Name** provides a choice of alternative units
 - User may add units
 - User may delete units

Unit Type	Default Unit	Unit Name	Unit Conversion Factor	Unit Description
Energy Quantities/Capacities	kboe	kBOE	1.000	Thousands of Barrels of Oil Equ
Energy Prices/O&M Costs	US \$/boe	\$/BOE	1.000	US Dollars per Barrel of Oil Equ
Costs	US \$1000	\$1000	1.000	Thousands of US Dollars
Emission Factors	kg/GJ	kg/GJ	1.000	Kilogram per Gigajoule
Emission Taxes	US \$/tonne	kg/TJ	1.000	US Dollars per metric tonne
Emissions	tonne	lb/MMBtu	1.000	Metric tonnes
		tonne/TJ		
		User Unit 1		
		User Unit 2		
		User Unit 3		
		User Unit 4		

Select User Unit 1-5 to add units to the list; define unit conversion factor

- Unit Conversion Factor** is used internally to convert the user-selected unit back to the default unit

Default Unit = New Unit * Unit Conversion Factor

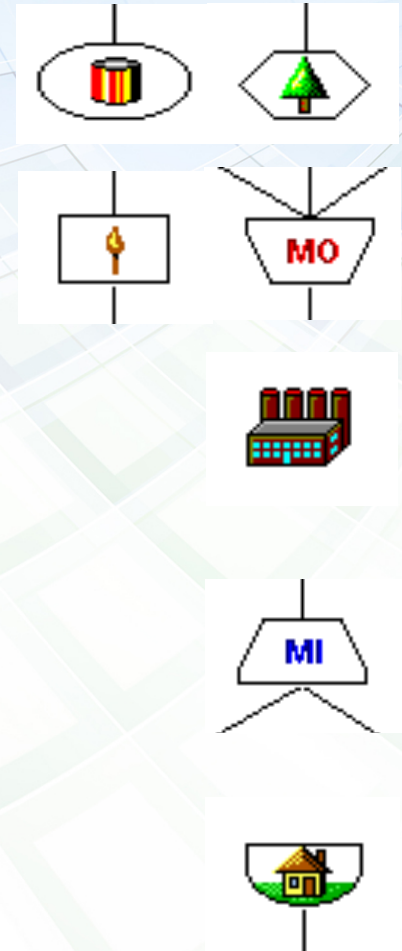
example: kg/GJ = kg/TJ * 0.001 TJ/GJ

- Note that the environmental units can only be selected if the “Perform Environmental Calculations” checkbox in Run Parameters is checked

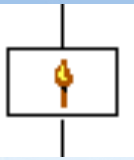


Emissions Are Calculated and Reported by Node

- For depletable and renewable resources, emissions are calculated based on the resource output
- For single input/single output and multiple output processes, emissions are calculated based on process fuel/energy input
- For thermal electric generating units, emissions are calculated based on fuel input or fuel consumption
- For multiple input nodes, emissions are calculated based on process output
 - Output based emission factor needs to be calculated and input as weighted average across all fuel inputs
- For demand nodes, emissions are calculated based on process input
 - Demand nodes should only be used for situations where sectors are modeled in terms of final energy



Example: Emission Factors for Conversion Process

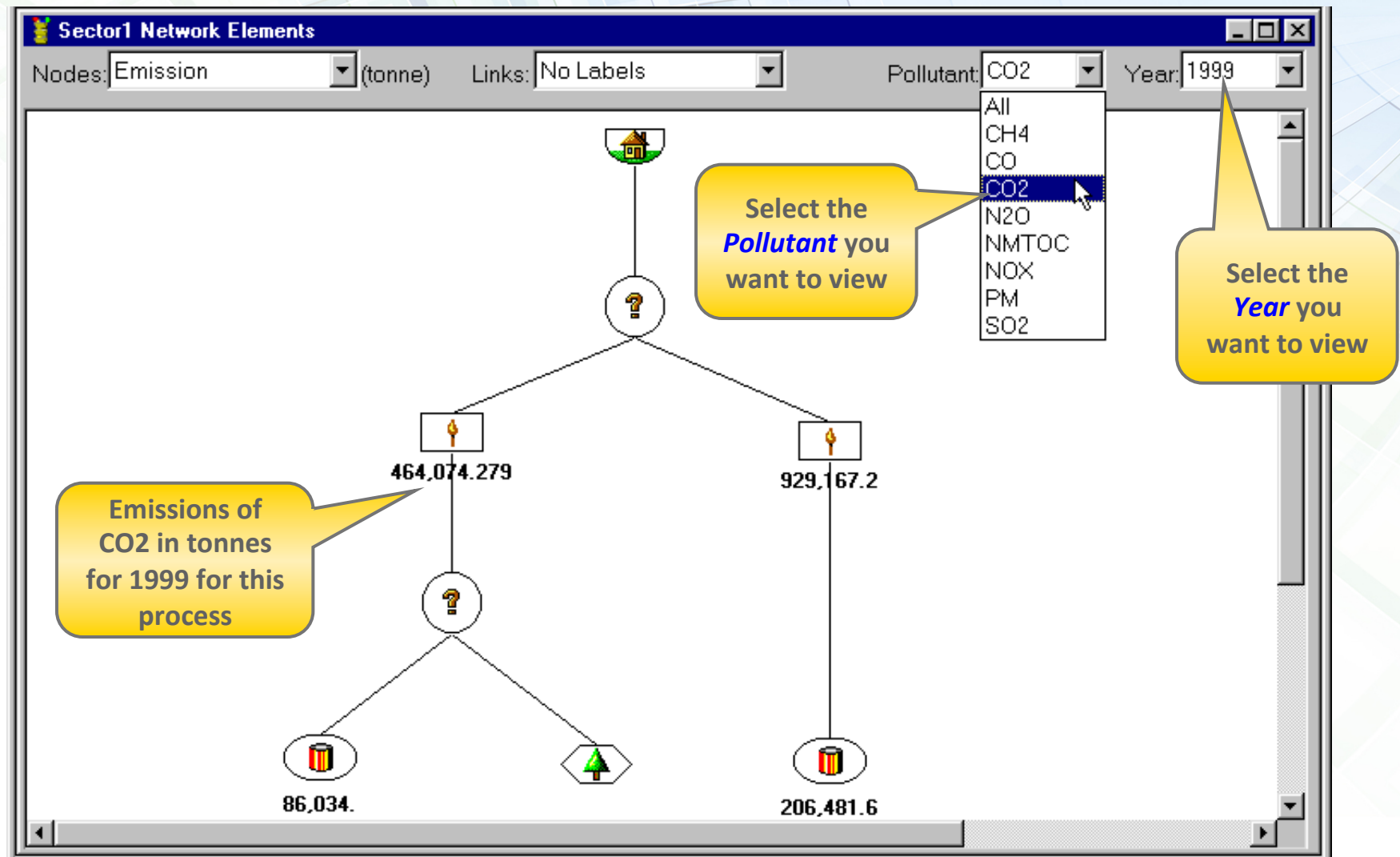


- **Uncontrolled Emission Factor Input Based** represents the emission factor for this specific process without using any pollution control technology; factor is based on the process input or fuel consumption
- **Scale Value** is the chemical content in percent that will be used to linearly scale the emissions
 - Scale value may be left blank if already included in emission factor (default 1.0)
 - For example CO2: enter 104.68 kg/GJ (1.349×77.6) and leave scale value blank; alternatively, enter 1.349 kg/GJ and 77.6% carbon
- **Emissions Tax** represents the tax imposed on a process for a specific pollutant
- All three parameters above can be changed year by year

Technical Properties		Economic Properties		Emissions Properties		Control Properties
Year	Pollutant Abbreviation	Uncontrolled Emission Factor Input Based (kg/GJ)	Chemical Scale	Scale Value (%)	Emissions Tax (\$/tonne)	
1999	CH4	0.001				
	CO2	1.349	Carbon	77.60		20.00
	N2O	0.002				
	NMTOC	0.001				
		0.399				
	PM	0.184	Ash	17.50		
	SO2	0.698	Sulfur	4.50		100.00

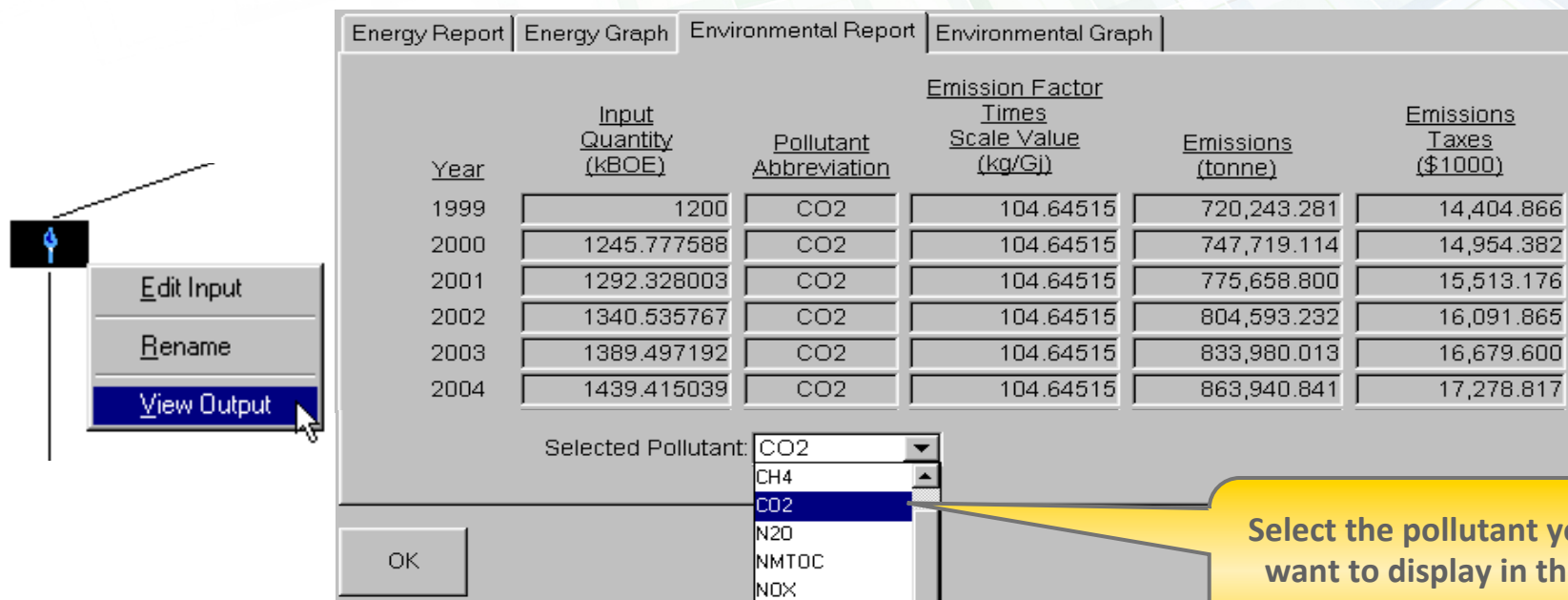
Chemical scale is defined in the *Run Parameters – Pollutants* screen

Environmental Results Can be Viewed Directly in the Network Using the Node Overlays



Environmental Reports and Graphs Can be Accessed for Each Node Using “View Output”

- Results can be viewed for each pollutant individually by using the **Selected Pollutant** pull-down menu or for all pollutants at the same time
- The pollutant selection in this screen will influence what will be displayed in the environmental graph screen



The screenshot displays the 'Environmental Report' window. On the left, a context menu is open with three options: 'Edit Input', 'Rename', and 'View Output'. The 'View Output' option is highlighted. The main window contains a table with the following data:

Year	Input Quantity (kBOE)	Pollutant Abbreviation	Emission Factor Times Scale Value (kg/GJ)	Emissions (tonne)	Emissions Taxes (\$1000)
1999	1200	CO2	104.64515	720,243.281	14,404.866
2000	1245.777588	CO2	104.64515	747,719.114	14,954.382
2001	1292.328003	CO2	104.64515	775,658.800	15,513.176
2002	1340.535767	CO2	104.64515	804,593.232	16,091.865
2003	1389.497192	CO2	104.64515	833,980.013	16,679.600
2004	1439.415039	CO2	104.64515	863,940.841	17,278.817

Below the table, the 'Selected Pollutant' dropdown menu is open, showing a list of pollutants: CO2, CH4, CO2, N2O, NMT0C, and NOX. The 'CO2' option is selected and highlighted in blue.

Select the pollutant you want to display in the report and in the graph

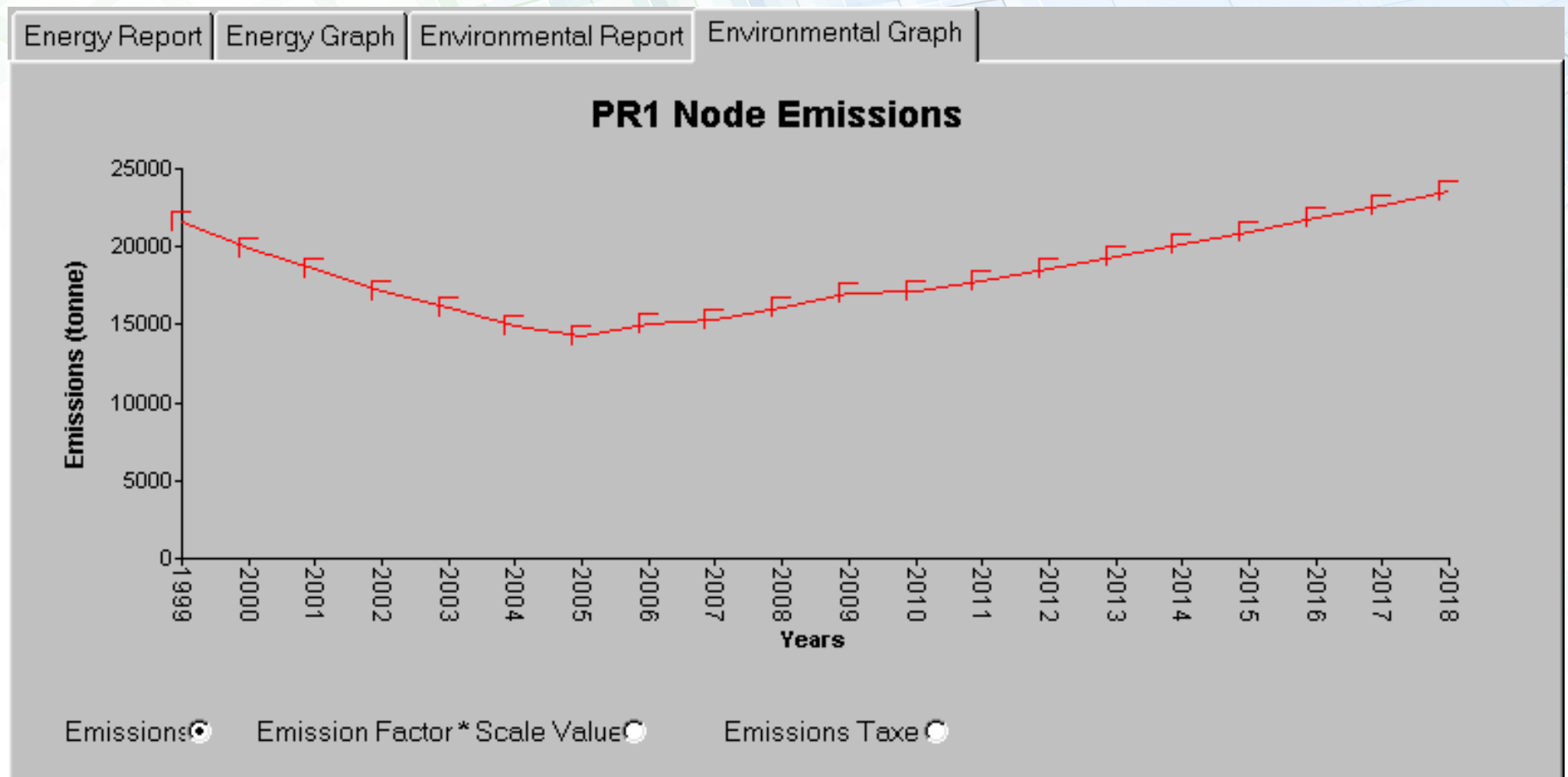
Environmental Reports and Graphs Can be Accessed for Each Node Using “View Output” (cont’d)

- ***Input Quantity*** reports the annual fuel consumption for this process
- ***Pollutant Abbreviation*** indicates which pollutant you are viewing
- ***Emission Factor Times Scale Value*** displays the combined or aggregate emission factor including the chemical scale for the selected pollutant
- ***Emissions*** reports the annual pollutant release for this process for the selected pollutant
- ***Emission Taxes*** displays the annual pollution taxes incurred by this process for this pollutant
 - There may be taxes on more than one pollutant
 - Taxes are calculated using the following equation

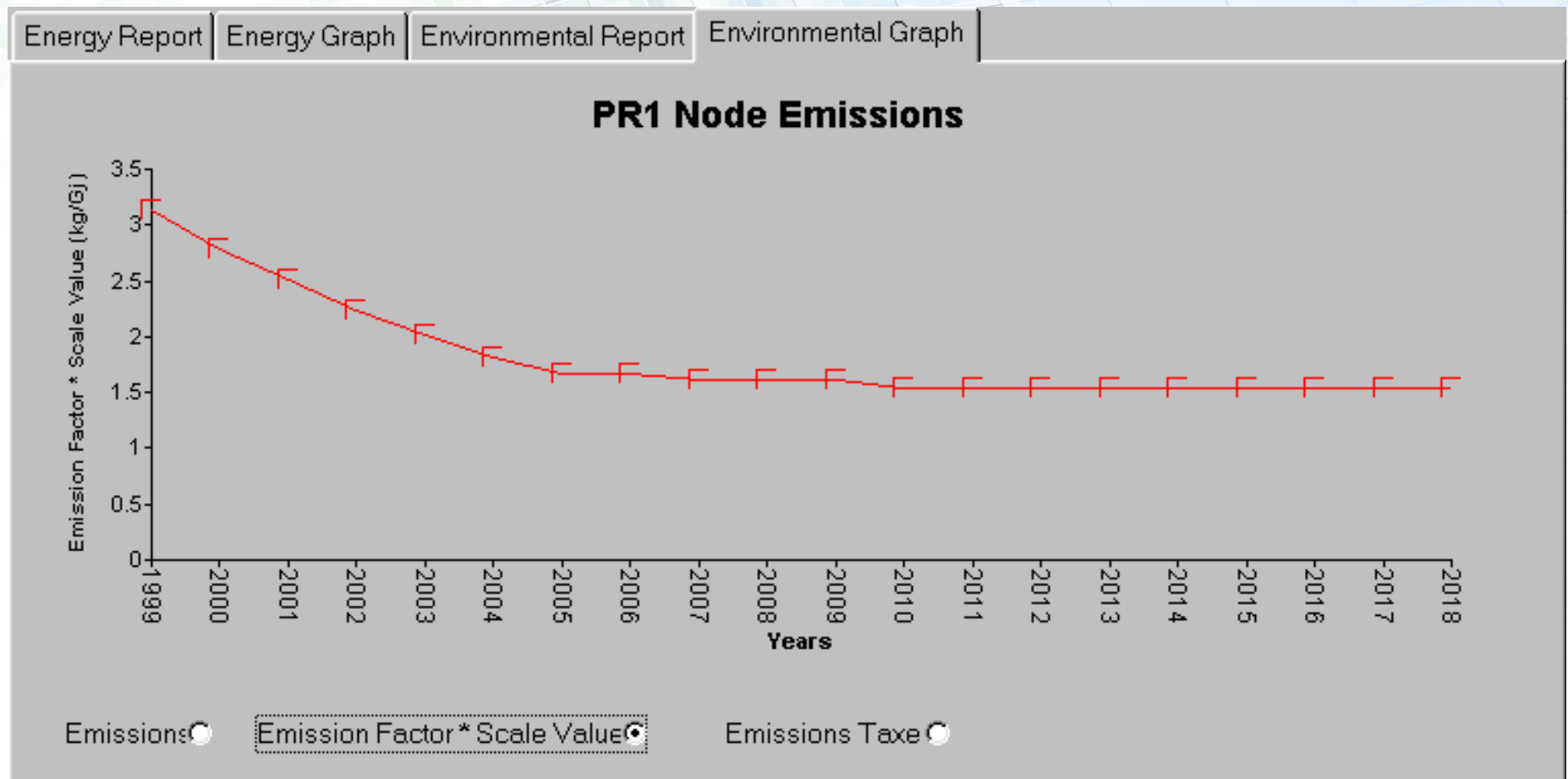
$$\text{Annual Emission Tax} = \text{Annual Emissions} \times \text{Emission Tax per tonne}$$



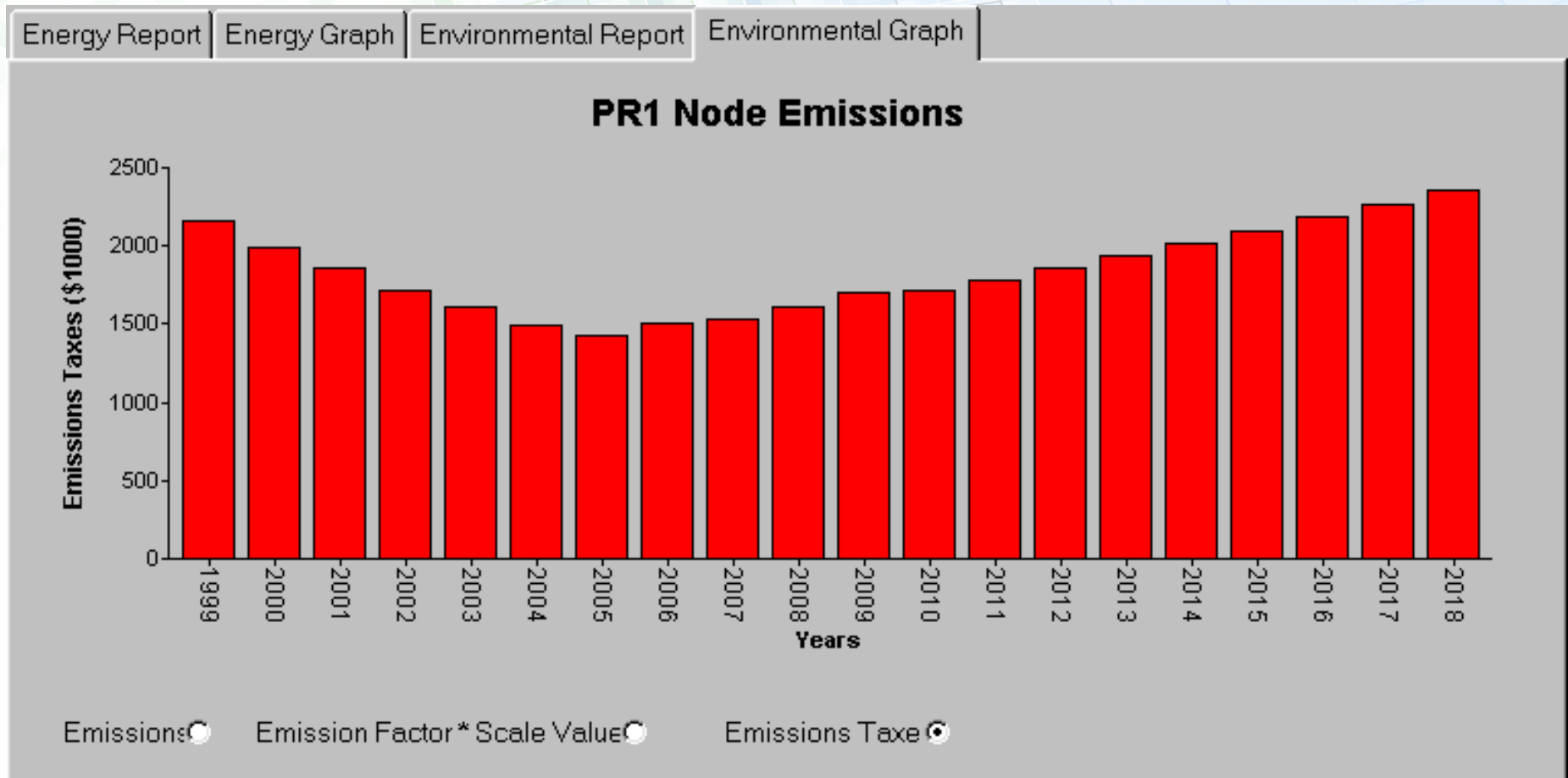
The Environmental Graph Shows Emission Results for the Pollutant(s) Selected in the Environmental Report



The Environmental Report Can Also be Used to View the Change in Emission Factor over Time



The Environmental Report Can be Used to Display the Annual Emissions Taxes Incurred by this Process



System-wide Emissions Results Can be Exported to EXCEL to Create Custom Reports and Graphs

The screenshot displays the **BALANCE for Windows** application window. The **File** menu is open, and the **Export Results** option is highlighted. A yellow callout bubble points to this menu item with the text: "Go to **File - Export Results**".

Below the menu, a grid of icons represents different system components: SERV, EXPO, RESI, INDU, TRAN, T&D, ELEC, FMIX, REFI, IMPO, NGAS, FEED, and COAL.

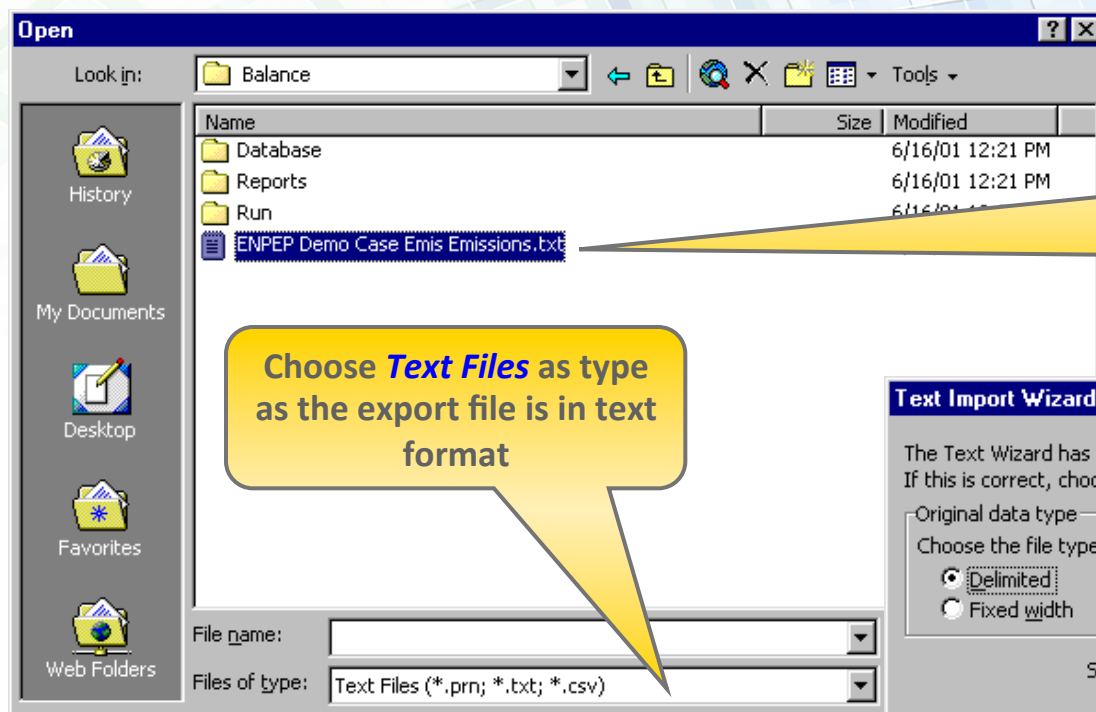
An **ENPEP for Windows** dialog box is open, asking: "Do you want to export the nodes emission information?". It has **Yes** and **No** buttons. A yellow callout bubble points to the **Yes** button with the text: "Click **Yes** when asked to export node emission information".

A **Select node Emissions Export File** dialog box is also open. It shows a file explorer view of the **Balance** folder, containing subfolders **Database**, **Reports**, and **Run**. The **File name** field is set to **ENPEP Demo Case Emis Emissions.txt**, and the **Save as type** is **Text Files (*.TXT)**. A yellow callout bubble points to the **Save** button with the text: "Specify the file name and location of the export file".

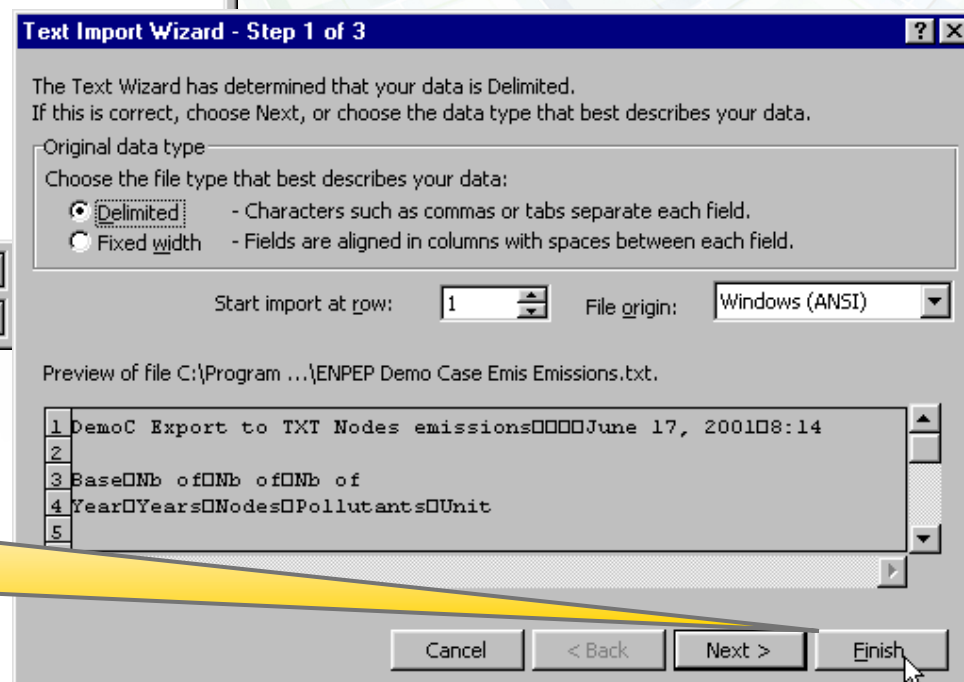
Exporting Emissions Results (cont'd)



Exporting Emissions Results (cont'd)



Start EXCEL, go to **File Open**, and browse to the folder where the export file is located. The default directory is `..\enpepwin\balance`



Exporting Emissions Results (cont'd)

Microsoft Excel - ENPEP Demo Case Emis Emissions.txt

File Edit View Insert Format Tools Data Window Help

Sort... Filter Form... Subtotals... Validation... Table... Text to Columns... Consolidate... Group and Outline... PivotTable and PivotChart Report... Get External Data Refresh Data

Go to **Data - Pivot Table** to quickly create a custom report for emissions by pollutant and sector

	A	B	C		H	I											
1	DemoC	Export to TXT	Nodes emis														
2																	
3	Base	Nb of	Nb of														
4	Year	Years	Nodes														
5																	
6	1991	30	79														
7																	
8																	
9	Sector	Node	Type		1993	1994	1995	1996	1997	1998	1999	2000					
10	AGRI	DE23	DE	0	874	1906.544	1990.431	2076.816	2166.119	2260.345	2360.705	2469.297					
11	AGRI	DE23	DE	1	0	0	0	0	0	0	0	0					
12	AGRI	DE23	DE	2	585	16.45812	17.18228	17.92799	18.69889	19.5123	20.37864	21.31606					
13	AGRI	DE23	DE	3NOX	282.5357	296.6624	310.5759	324.8314	339.1239	353.8419	369.0571	385.1111	402.2101	420.7117			
14	AGRI	DE23	DE	4CO	2563.163	2691.322	2817.545	2946.87	3076.532	3210.054	3348.086	3493.728	3648.85	3816.697			
15	AGRI	DE23	DE	5NMTO	0	0	0	0	0	0	0	0	0	0			
16	AGRI	DE23	DE	6CH4	0	0	0	0	0	0	0	0	0	0			
17	AGRI	DE23	DE	7TOC	41.43856	43.51049	45.55113	47.64193	49.73818	51.89682	54.12838	56.48296	58.99081	61.70439			
18	AGRI	DE23	DE	8CO2	414586.8	435316.1	455732.5	476650.6	497623.2	519220.1	541546.6	565103.8	590194.5	617343.7			
19	AGRI	DE23	DE	9N2O	0	0	0	0	0	0	0	0	0	0			
20	AGRI	DE24	DE	0PM	4.230636	4.442168	4.650506	4.863964	5.077978	5.298363	5.526192	5.766582	6.022618	6.299658			
21	AGRI	DE24	DE	1PM10	4.230636	4.442168	4.650506	4.863964	5.077978	5.298363	5.526192	5.766582	6.022618	6.299658			
22	AGRI	DE24	DE	2SO2	6.3459								9.033927	9.449487			
23	AGRI	DE24	DE	3NOX	141.30								201.1554	210.4086			
24	AGRI	DE24	DE	4CO	16.711								23.78934	24.8836			
25	AGRI	DE24	DE	5NMTO	3.3845								4.818094	5.039727			

Export data provides emissions results by sector, node, pollutant, and year



Exporting Emissions Results (cont'd)

PivotTable and PivotChart Wizard - Step 1 of 3

Where is the data that you want to analyze?

☒ Microsoft Excel list or database
☐ External data source
☐ Multiple consolidation ranges
☐ Another PivotTable or PivotChart

What kind of report do you want to create?

☒ PivotTable
☐ PivotChart (with PivotTable)

Cancel < Back Next > Finish

Accept the default settings and click **Finish**

Select the data range that contains the header row and the data

	B	C	D	E	F	H	I
	Report to TXT	Nodes emissions	17-Jun-01				
3	Base	Nb of	Nb of	Nb of			
4	Year	Years	Nodes	Pollutants	Unit		
5							
6	1991	30	79	10	tonne		
7							
8							
9	Sector	Node	Type	Pollutant	1991	1992	1993
10	AGRI	DE23	DE	OPM	1658.296	174.11	1822.874
11	AGRI	DE23	DE	1PM10	0	0	0
12	AGRI						
13	AGRI						
14	AGRI	DE23	DE	4CO	2563.163	2691.322	2817.545
15	AGRI	DE23	DE	5NMTO	0	0	0
16	AGRI	DE23	DE	6CH4	0	0	0
17	AGRI	DE23	DE	7TOC	41.43856	43.51049	45.55113
18	AGRI	DE23	DE	8CO2	414586.8	435316.1	455732.5
19	AGRI	DE23	DE	9N2O	0	0	0
20	AGRI	DE24	DE	OPM	4.230636	4.442168	4.650506
21	AGRI	DE24	DE	1PM10	4.230636	4.442168	4.650506
22	AGRI	DE24	DE	2SO2	6.345954	6.663252	6.975758
23	AGRI	DE24	DE	3NOX	141.3032	148.3684	155.3269
24	AGRI	DE24	DE	4CO	16.71101	17.54656	18.3695
25	AGRI	DE24	DE	5NMTO	3.384509	3.553734	3.720405

PivotTable and PivotChart Wizard - Step 2 of 3

Where do you want to put the PivotTable?

☒ New worksheet
☐ Existing worksheet

Click Finish to create your PivotTable.

Layout... Options... Cancel < Back Next > Finish

Accept the default settings and click **Finish**

Exporting Emissions Results (cont'd)

PivotTable and PivotChart Wizard - Layout

Construct your PivotTable by dragging the field buttons on the right to the diagram on the left.

Drag Sector field to the *Column* area

Drag Pollutant field to the *Page* area

Drag the years you want to show in your table/graph to the *Data* area. Make sure the field says "Sum of xxxx"

Sum of	TA
1991	
1995	
2000	
2005	
2010	
2015	
2020	

Sector	1996	2005
Node	1997	2006
Type	1998	2007
Pollutant	1999	2008
1991	2000	2009
1992	2001	2010
1993	2002	2011
1994	2003	2012
1995	2004	2013

Help OK Cancel



Exporting Emissions Results (cont'd)

	A	B	C	D	E	F	G	H	I	J	K	L
1		Pollutant	8CO2									
2												
3			Sector									
4		Data	AGRI	COAL	ELEC	FMIX	INDU	REFI	RESI	SERV	TRAN	Grand Total
5	1991	Sum of 1991	1,149,057	0	15,414,470	1,962	12,273,706	1,118,393	2,417,921	4,938,058	7,458,533	44,772,100
6	1995	Sum of 1995	1,379,198	0	24,450,304	0	13,592,133	1,307,607	2,563,915	6,003,888	8,951,511	58,248,557
7	2000	Sum of 2000	1,711,011	0	40,383,535	0	19,478,998	1,307,607	2,713,511			92,761
8	2005	Sum of 2005	2,189,336	0	57,088,782	0	26,005,222	1,307,607	3,043,511			108,693
9	2010	Sum of 2010	2,860,558	0	80,056,027	0	25,683,680	1,307,607	3,043,511			68,164
10	2015	Sum of 2015	2,860,558	0	80,056,027	0	24,528,976	1,307,607	2,796,721			128,459
11	2020	Sum of 2020	2,860,558	0	80,056,027	0	24,399,614	1,307,607	2,642,941			131,946

Insert column with years to use in the graph as x-axis values

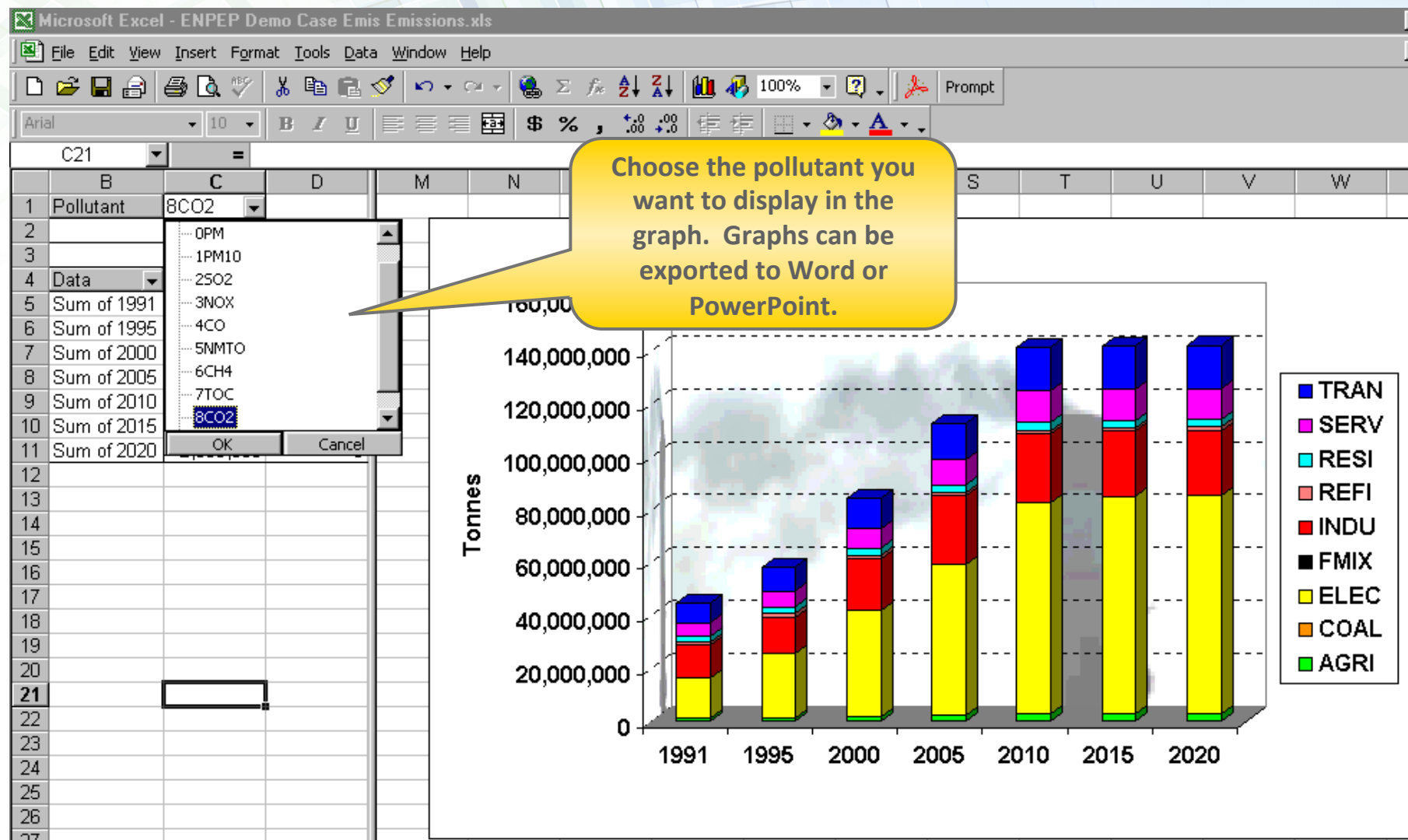
Use formatting commands to customize the pivot table report

	A	B	C	D	E	F	G	H	I	J	K	L
1		Pollutant	1PM10									
2												
3												
4		Data										Grand Total
5	1991	Sum of 1991	1PM10		348	1	15,784					97,700
6	1995	Sum of 1995	25O2		263	0	28,698					158,882
7	2000	Sum of 2000	3NOX		603	0	41,211					256,047
8	2005	Sum of 2005	4CO		549	0	55,801					358,968
9	2010	Sum of 2010	5NMTO		462	0	57,053	771	693	758	0	481,557
10	2015	Sum of 2015	6CH4		370	0	54,719	771	660	758	0	491,098
11	2020	Sum of 2020	7TOC		932	0	54,373	771	637	758	0	493,290
12			8CO2									

Select the pollutant you want to view. Table and graph automatically gets updated

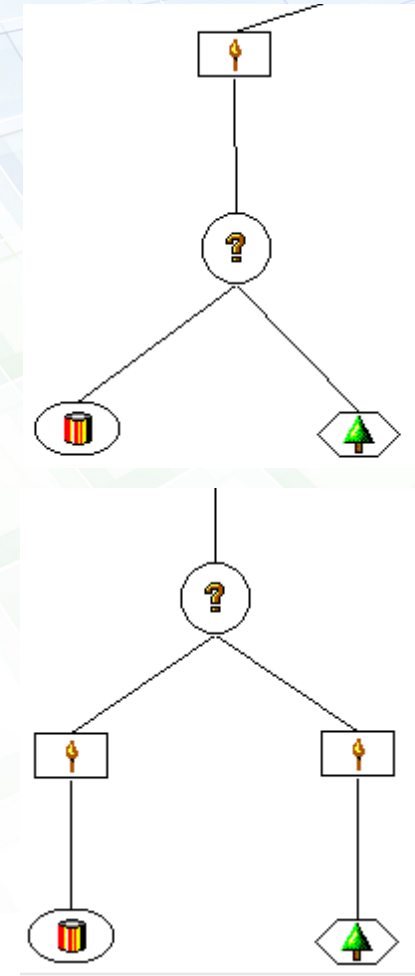


Exporting Emissions Results (cont'd)



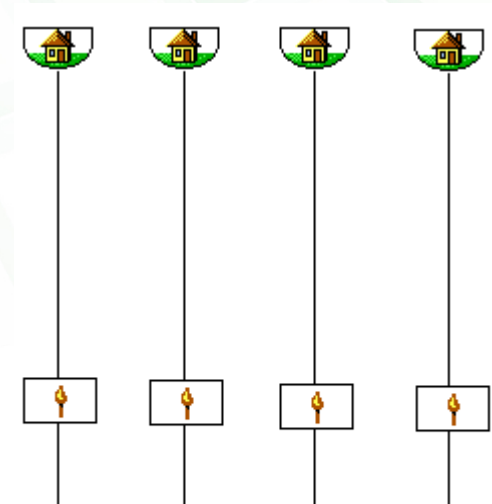
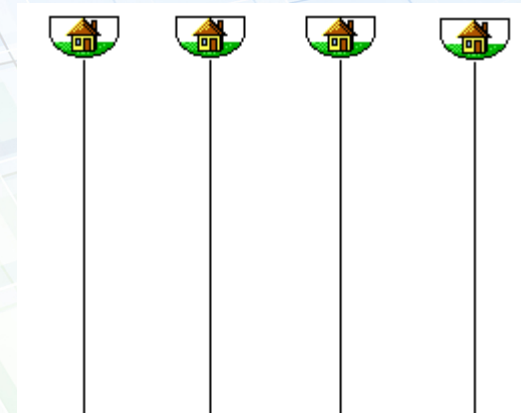
Some Modeling Issues

- If your process is using a mix of fuels that changes every year (e.g., oil and gas), your average emission factor also changes every year
- The fuel mix, and thus the average emission factor may be different in each scenario
- The current version of the model does not track this information
- User needs to ensure consistency
- One way to do this is to compute an average emission factor year-by-year and enter the values into the model (this may have to be done for each of your scenarios)
- A better way to do this is by modifying the network structure
- The modified structure would make sure that each process uses just one type of fuel



Some Modeling Issues (cont'd)

- If your end use sectors are mostly in final energy structure without any conversion processes, emissions will not be accounted for
- One way to deal with this is to include emission factors into the demand nodes
 - If demand nodes are projecting a mix of fuels, the emission factors need to account for this by using a weighted average based on the mix ratio
 - When converting the sector into useful energy demand by inserting conversion processes, the emission factors in the demand nodes must be deleted
- Another way to deal with this is to include so-called “dummy” processes
 - Single input/single outputs
 - Efficiency 1.0, no cost, no change in energy flows
 - Only to obtain emissions for sectors with final energy



Example: Simple Network with Emissions

ENPEP for Windows

File Edit Window Help

BAL Example Networks Cases

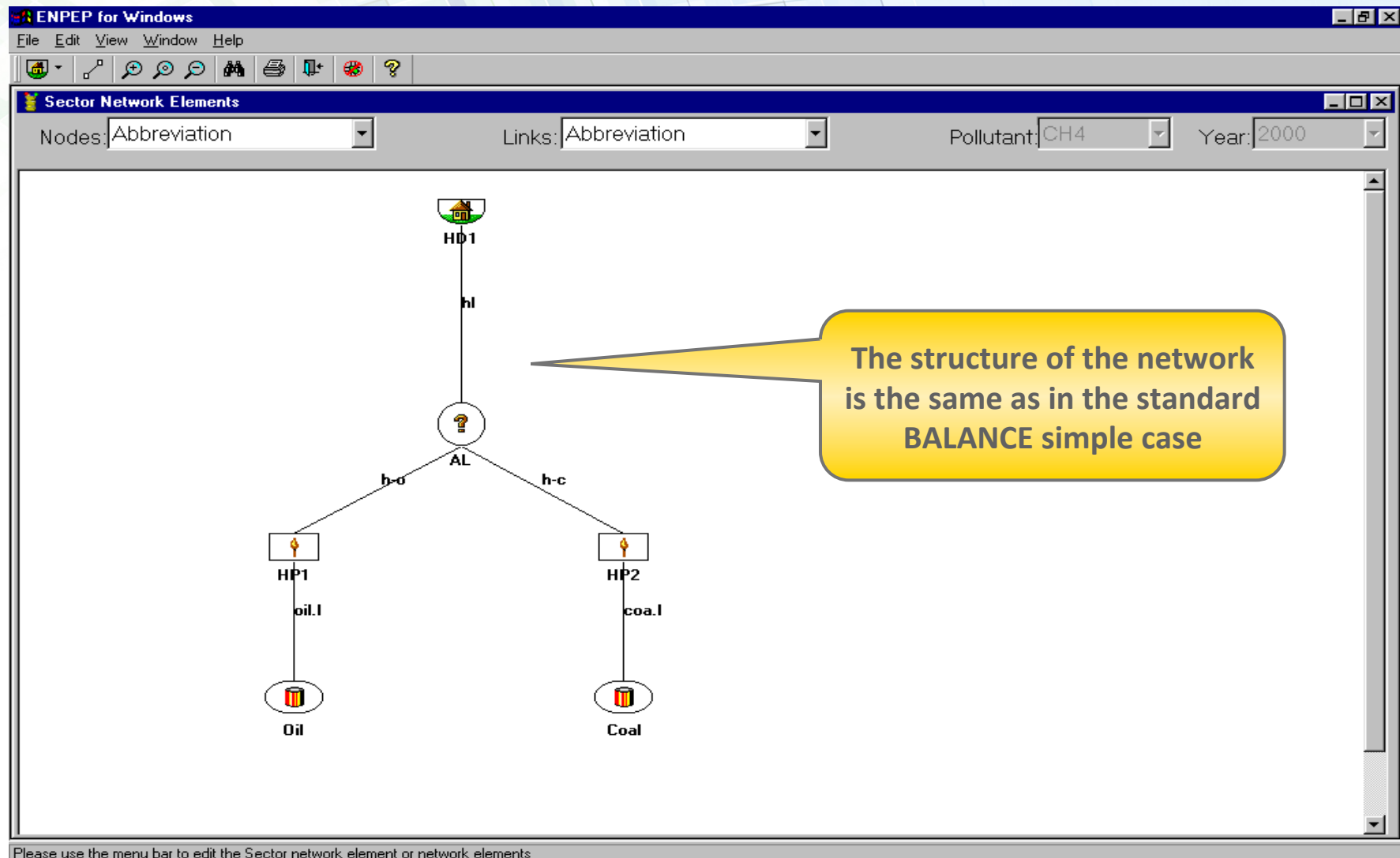
Name	Abbreviation	Description
BAL Simple Case / E	BAL-E	BALANCE Standard Simple Case with environmental calculations Start Year: 2000 End Year: 2019
BALANCE Ref. Case	BAL-R	BALANCE Standard Refinery Case for use at training courses Start Year: 2000 End Year: 2019
BALANCE Simple Case	BAL-S	BALANCE Standard Simple Case for use at training courses Start Year: 2000 End Year: 2019

BALANCE simple case will be modified to include environmental calculations

New Case Name: Abbr.: New Case Description:

OK Cancel Add Delete Start Year: 2000 End Year: 2019

Example: Simple Network with Emissions



Example: Simple Network with Emissions

ENPEP for Windows

File Edit Window Help

BAL-E Case Properties

Run Parameters Pollutants Output Codes Non-electric Units Electric Units

Convergence Parameters:

Relative Tolerance: 0.100 (Fraction)

Absolute Tolerance: 10.000 (kboe)

Maximum Iterations: 10 (1-100)

Lower Bound Relaxation Range: 0.100

Upper Bound Relaxation Range: 0.900

Perform Environmental Calculations: ☒

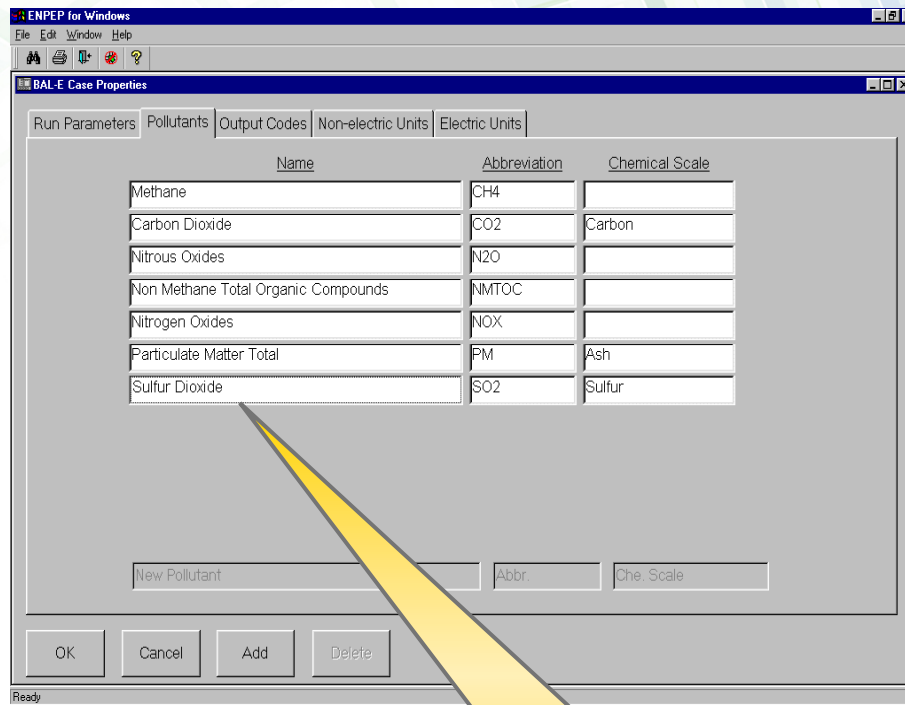
Perform Environmental Calculations must be activated

OK Cancel Add Delete

Ready



Example: Simple Network with Emissions



ENPEP for Windows

BAL-E Case Properties

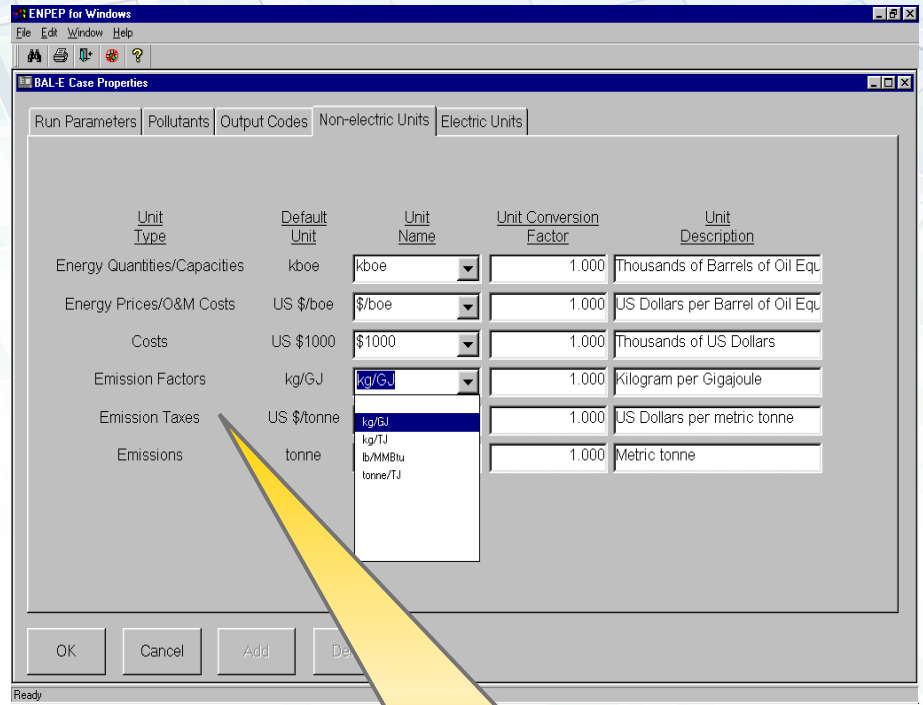
Run Parameters | Pollutants | Output Codes | Non-electric Units | Electric Units

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

New Pollutant: Abbr.: Che. Scale:

OK Cancel Add Delete

Check the list of pollutants and modify if necessary



ENPEP for Windows

BAL-E Case Properties

Run Parameters | Pollutants | Output Codes | Non-electric Units | Electric Units

Unit Type	Default Unit	Unit Name	Unit Conversion Factor	Unit Description
Energy Quantities/Capacities	kboe	kboe	1.000	Thousands of Barrels of Oil Eq.
Energy Prices/O&M Costs	US \$/boe	\$/boe	1.000	US Dollars per Barrel of Oil Eq.
Costs	US \$1000	\$1000	1.000	Thousands of US Dollars
Emission Factors	kg/GJ	kg/GJ	1.000	Kilogram per Gigajoule
Emission Taxes	US \$/tonne	kg/GJ	1.000	US Dollars per metric tonne
Emissions	tonne	kg/TJ lb/MMBtu tonne/TJ	1.000	Metric tonne

OK Cancel Add Delete

Check the emission factor and emissions units and modify if necessary



Example: Simple Network with *Uncontrolled Emissions*

ENPEP for Windows

File Edit Window Help

Coal Depletable Resource Node Properties

Technical Properties | Economic Properties | Emissions Properties

Year	Pollutant Abbreviation	Uncontrolled Emission Factor Output Based (kg/GJ)	Chemical Scale	Scale Value (%)	Emissions Tax (\$/tonne)
2000	CH4	0.300			
	CO2		Carbon		
	N2O				
	NMTOC				
	NOX				
2001	PM		Ash		
	SO2		Sulfur		
	CH4				
	CO2		Carbon		
	N2O				
	NMTOC				
	NOX				

Enter CH₄ emission factor for coal mining

OK Cancel Duplicate Up Column Duplicate Down Column

Ready

COAL MINING: methane (CH₄) emissions = 10 m³/tonne of coal (range 0.3-24) = 0.5 m³/GJ (1 tonne of coal = 20 GJ) = **0.3 kg CH₄/GJ** (1 m³ CH₄ = 0.6 kg)

Example: Simple Network with **Uncontrolled Emissions**

ENPEP for Windows

File Edit Window Help

HP2 Conversion Process Node Properties

Technical Properties Economic Properties Emissions Properties

Year	Pollutant Abbreviation	Uncontrolled Emission Factor Input Based (kg/GJ)	Chemical Scale	Scale Value (%)	Emissions Tax (\$/tonne)
2000	CH4		Carbon		
	CO2				
	N2O				
	NMTOC		Ash		
	NOX				
	PM	2.500			
2001	SO2		Sulfur		
	CH4				
	CO2				
	N2O		Carbon		
	NMTOC				
	NOX				

OK Cancel Duplicate Up Column Duplicate Down Column

Ready

Enter PM emission factor for coal combustion

COAL COMBUSTION (PM): 1 kg coal with 10% ash = 0.1 kg ash generated = 0.05 kg bottom ash + 0.05 kg fly ash => 0.05 kg fly ash / kg coal = 50 kg/tonne
 = **2.5 kg PM/GJ** (1 tonne of coal = 20 GJ) - **uncontrolled emissions**



Example: Simple Network with **Uncontrolled Emissions**

ENPEP for Windows

File Edit Window Help

HP2 Conversion Process Node Properties

Technical Properties | Economic Properties | Emissions Properties

Year	Pollutant Abbreviation	Uncontrolled Emission Factor Input Based (kg/GJ)	Chemical Scale	Scale Value (%)	Emissions Tax (\$/tonne)
2000	CH4				
	CO2		Carbon		
	N2O				
	NMTOC				
	NOX				
	PM	2.500	PM		
2001	SO2	0.900	Sulfur		
	CH4				
	CO2		Carbon		
	N2O				
	NMTOC				
	NOX				

OK Cancel Duplicate Up Column Duplicate Down Column

Ready

Enter SO₂ emission factor for coal combustion

COAL COMBUSTION (SO₂): 1 kg coal with 1% sulfur = 0.01 kg S generated
 = 0.02 kg SO₂ (molar ratio SO₂/S = 64/32 = 2.0) generated = 0.018 kg emitted (90%
 oxidization) => 0.018 kg SO₂ / kg coal = 18 kg/tonne = **0.9 kg SO₂/GJ**
 (1 tonne of coal = 20 GJ) - **uncontrolled emissions**

Example: Simple Network with **Uncontrolled Emissions**

ENPEP for Windows

File Edit Window Help

HP2 Conversion Process Node Properties

Technical Properties | Economic Properties | Emissions Properties

Year	Pollutant Abbreviation	Uncontrolled Emission Factor Input Based (kg/GJ)	Chemical Scale	Scale Value (%)	Emissions Tax (\$/tonne)
2000	CH4				
	CO2	125.0	Carbon		
	N2O				
	NMTOC				
	NOX				
2001	PM	2.500	Ash		
	SO2	0.900	Sulfur		
	CH4				
	CO2		Carbon		
	N2O				
	NMTOC				
	NOX				

OK Cancel Duplicate Up Column Duplicate Down Column

Ready

Enter CO₂ emission factor for coal combustion

COAL COMBUSTION (CO₂): 1 kg coal with 70% C = 0.7 kg C generated
 = 2.5 kg CO₂ (molar ratio CO₂/C = 44/12 = 3.664) generated = 2.5 kg emitted (100%
 oxidization) => 2.5 kg CO₂ / kg coal = 2500 kg/tonne = **125 kg CO₂/GJ**
 (1 tonne of coal = 20 GJ) - **uncontrolled emissions**

Example: Simple Network with *Uncontrolled Emissions*

ENPEP for Windows

File Window Help

Coal Node Report

Energy Report Energy Graph Environmental Report Environmental Graph

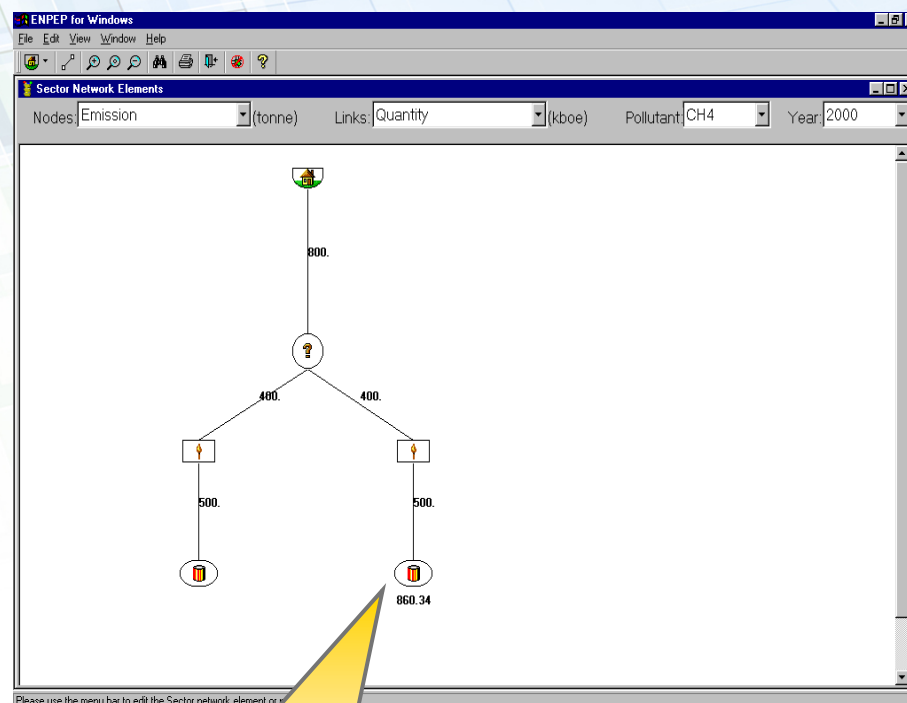
Year	Output Quantity (kboe)	Pollutant Abbreviation	Emission Factor Times Scale Value (kg/GJ)	Emissions (tonne)	Emissions Taxes (\$1000)
2000	500.000	CH4	0.30000	860.340	0.000
		CO2	0.00000	0.000	0.000
		N2O	0.00000	0.000	0.000
		NMTOC	0.00000	0.000	0.000
		NOX	0.00000	0.000	0.000
2001	500.000	PM	0.00000	0.000	0.000
		SO2	0.00000	0.000	0.000
		CH4	0.30000	860.340	0.000
		CO2	0.00000	0.000	0.000
		N2O	0.00000	0.000	0.000

Selected Pollutant: All

OK

Ready

Results for coal mine:
environmental report/
graph



Results for coal mine:
environmental network
info

Example: Simple Network with *Uncontrolled Emissions*

ENPEP for Windows

HP2 Node Report

Energy Report | Energy Graph | Environmental Report | Environmental Graph

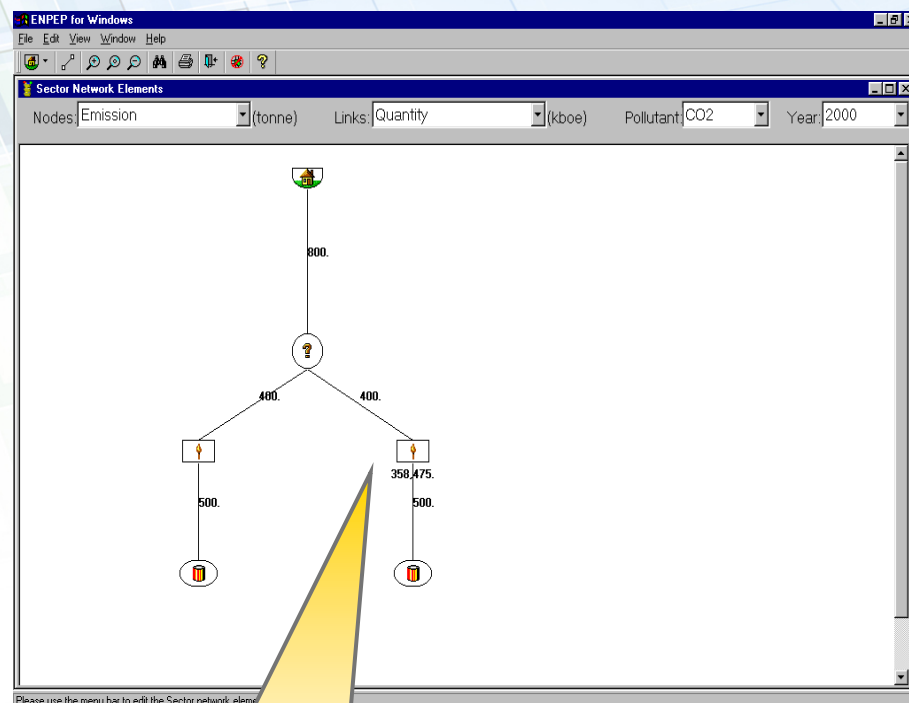
Year	Input Quantity (kboe)	Pollutant Abbreviation	Emission Factor Times Scale Value (kg/GJ)	Emissions (tonne)	Emissions Taxes (\$1000)
2000	500.000	CH4	0.00000	0.000	0.000
		CO2	125.00000	358,475.000	0.000
		N2O	0.00000	0.000	0.000
		NMTOC	0.00000	0.000	0.000
		NOX	0.00000	0.000	0.000
2001	500.000	PM	2.50000	7,169.500	0.000
		SO2	0.90000	2,581.020	0.000
		CH4	0.00000	0.000	0.000
		CO2	125.00000	358,475.000	0.000
		N2O	0.00000	0.000	0.000

Selected Pollutant: All

OK

Ready

Results for coal boiler:
environmental report/
graph



Results for coal boiler:
environmental network
info

Example: Simple Network with **Controlled Emissions**

- Please note that the current version of ENPEP-BALANCE does not explicitly include emissions control technologies
 - This feature may be introduced in future versions
- To model controlled emissions (e.g., for PM, SO₂, NO_x) with the current version
 - Recalculate the emission factors based on the uncontrolled emission factor and the average control efficiency as below
 - Enter the controlled emission factor into the uncontrolled emission factor field
 - If available, emission control costs can be added to the conversion process or plant economic properties
 - Rerun the case

$$\text{Controlled Emission Factor} = \text{Uncontrolled Emission Factor} \times (1 - \text{Control Efficiency}/100)$$

- It may be advisable to keep 2 separate cases: one case with uncontrolled emission and one case with controlled emissions

*Example: Simple Network with **Controlled** Emissions*

- PM emissions from coal combustion
 - Uncontrolled emission factor: 2.5 kg PM/GJ
 - Abatement technology with 98% efficiency
 - Controlled emission factor: $2.5 \times (1 - 0.98) = 0.05$ kg PM/GJ

- SO₂ emissions from coal combustion
 - Uncontrolled emission factor: 0.9 kg SO₂/GJ
 - Abatement technology with 80% efficiency
 - Controlled emission factor: $0.9 \times (1 - 0.8) = 0.18$ kg SO₂/GJ

- CO₂ emissions from coal combustion
 - Uncontrolled emission factor: 125 kg CO₂/GJ
 - No abatement technology available



Example: Simple Network with **Controlled Emissions**

ENPEP for Windows

File Edit Window Help

HP2 Conversion Process Node Properties

Technical Properties | Economic Properties | Emissions Properties

Year	Pollutant Abbreviation	Uncontrolled Emission Factor Input Based (kg/GJ)	Chemical Scale	Scale Value (%)	Emissions Tax (\$/tonne)
2000	CH4				
	CO2	125.000	Carbon		
	N2O				
	NMTOC				
	NOX				
2001	PM	0.050	Ash		
	SO2	0.18	Sulfur		
	CH4				
	CO2		Carbon		
	N2O				
	NMTOC				
	NOX				

OK Cancel Duplicate Up Column Duplicate Down Column

Ready

Enter **Controlled PM** emission factor for coal combustion

Enter **Controlled SO₂** emission factor for coal combustion

