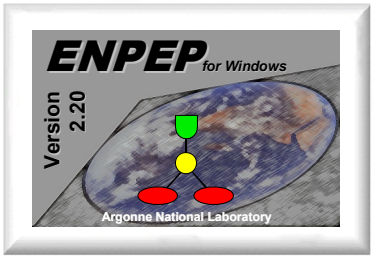
# Developing an Energy Supply and Demand Network: Supply Side

**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


ENERGY SUPPLY

# There are Many Ways to Display the Movement of Energy in a Country

- Energy balance table

## Energy balance table *

Member Economy: APEC
Year: 1999 actual (case: Reference)

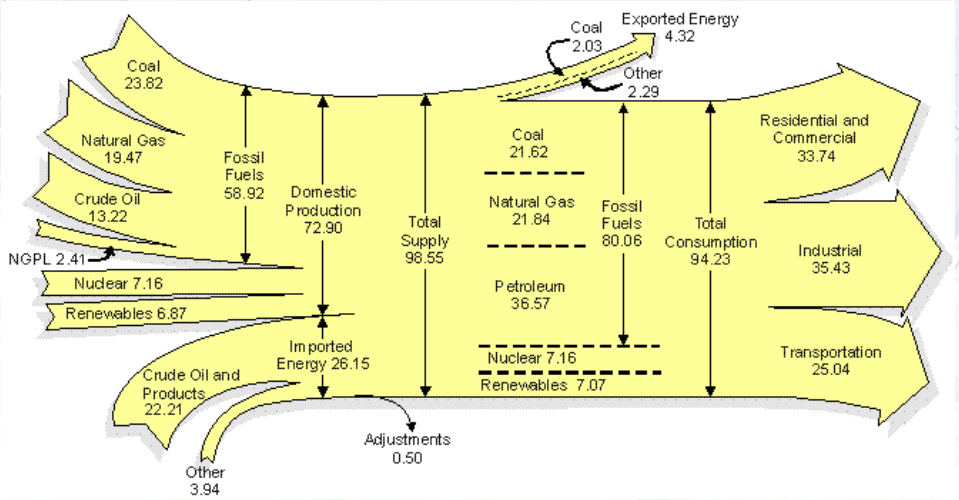
| Units: Mtoe | Coal [a] | Oil [b] | Gas [c] | Hydro | Nuclear | New and Renewables [d] | Electricity | Heat | Total |
|---|---|---|---|---|---|---|---|---|---|
| Production | 1,567.9 | 1,296.7 | 1,266.3 | 106.3 | 378.6 | 475.5 | | | 5,091.3 |
| Imports | 192.9 | 1,429.3 | 176.2 | | | 2.1 | 6.9 | | 1,807.4 |
| Exports [e] | (221.1) | (703.1) | (307.7) | | | (0.1) | (7.9) | | (1,240.0) |
| Primary energy supply | 1,539.6 | 2,022.9 | 1,134.7 | 106.3 | 378.6 | 477.5 | (0.9) | | 5,658.7 |
| Power and heat generation | (1,037.9) | (164.5) | (432.0) | (106.3) | (378.6) | (98.0) | 765.9 | 198.4 | (1,253.0) |
| Petroleum refineries [f] | (0.4) | (131.7) | (28.0) | | | (1.3) | (10.4) | (13.0) | (184.7) |
| Other | (148.5) | (16.6) | (139.0) | | | (8.9) | (119.6) | 18.5 | (446.1) |
| Final energy consumption | 364.2 | 1,702.2 | 517.6 | | | 369.1 | 635.1 | 171.9 | 3,760.0 |
| Industry [g] | 282.6 | 400.7 | 236.3 | | | 42.2 | 285.1 | 78.0 | 1,325.0 |
| Transport | 6.1 | 1,019.7 | 0.5 | | | 1.7 | 7.6 | 0.0 | 1,035.6 |
| Commercial | 13.0 | 67.3 | 92.4 | | | 3.0 | 163.7 | 19.8 | 359.3 |
| Residential | 53.8 | 97.9 | 188.3 | | | 322.0 | 178.7 | 71.6 | 912.3 |
| Other [h] | 8.6 | 116.6 | 0.0 | | | 0.2 | 0.0 | 2.5 | 127.8 |
| $CO_{2e}$ Emission [i] (Unit: $MtCO_{2e}$) | | | | | | | | | 13,882.5 |
| *from electricity generation* | | | | | | | | | 5,558.0 |

*Notes:* * *Figures may not balance due to statistical discrepancy.*

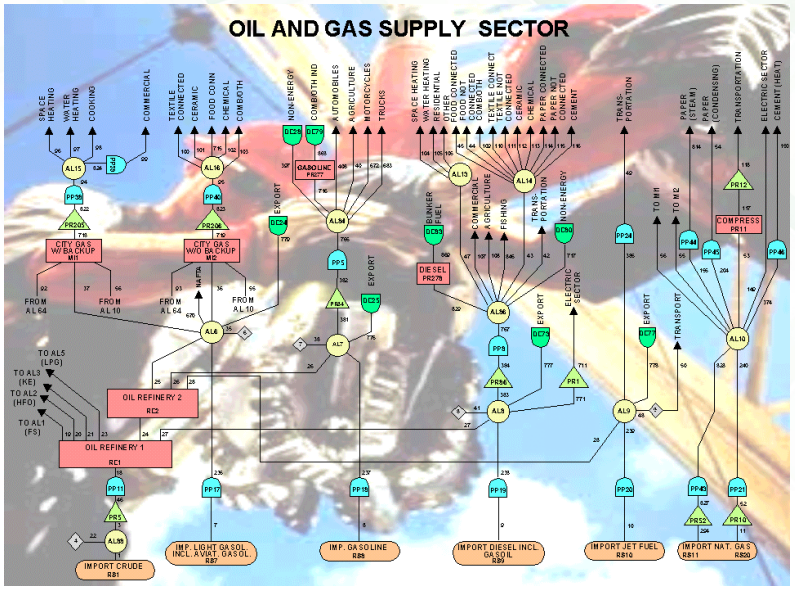
*a Coal refers to raw coal and coal products. b Includes crude oil and petroleum products, such as gasoline, diesel, LPG, naphtha, fuel oil, etc.*
*c Includes natural gas and town gas. d Includes geothermal, wind, Solar, tidal and biomass.*
*e Includes exports, stock changes and international marine bunkers. f Includes auxiliary fuel use. g Includes agriculture and construction sectors.*
*h Includes non-energy use and 'Other' sectors not classified. i Emissions of carbon dioxide, methane and nitrous oxide.*

# *There are Many Ways to Display the Movement of Energy in a Country*

- Energy flow diagram



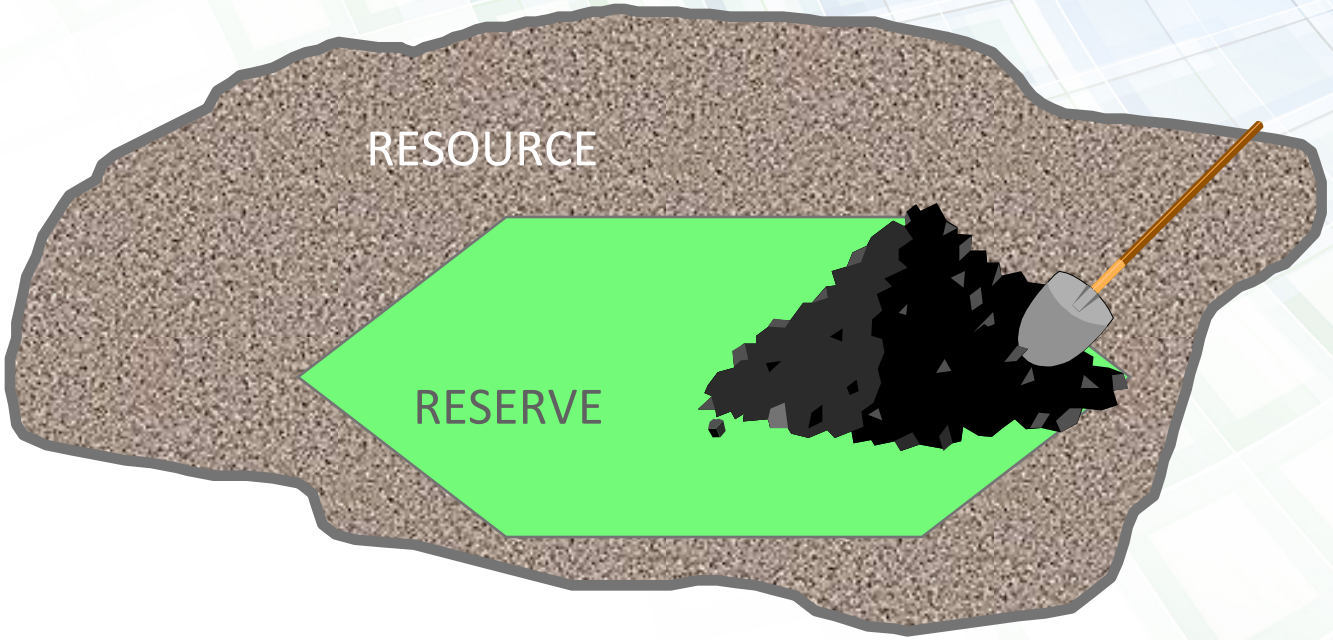

- Energy network



# *It is Important to Define Terms*

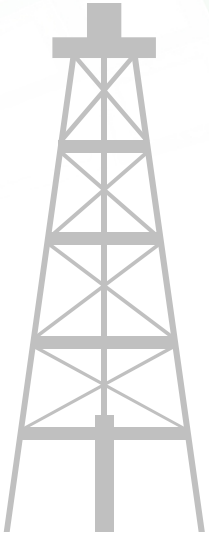

**There is no universal convention on terms**

# *Energy Resource Is The Un-recovered, Un-processed Energy*

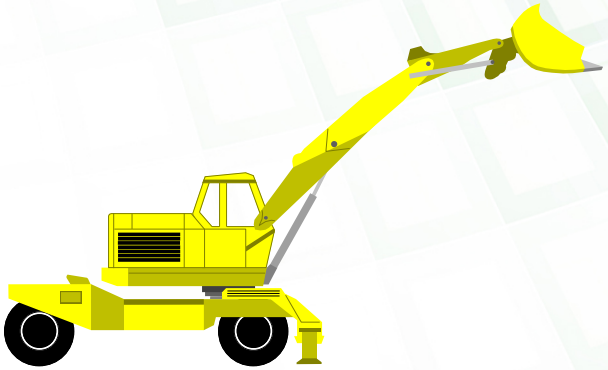



**<u>Energy Reserve</u> is the economically recoverable portion of the resource**

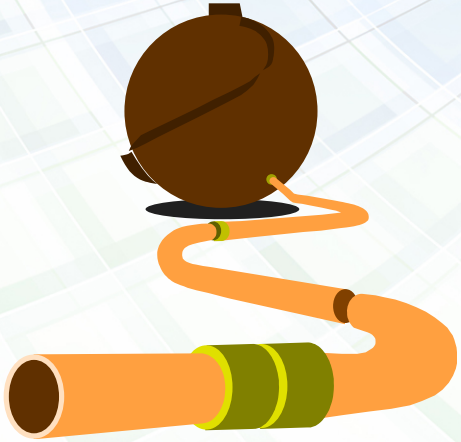
# *Primary Energy Production is the Energy That is Extracted*



Oil

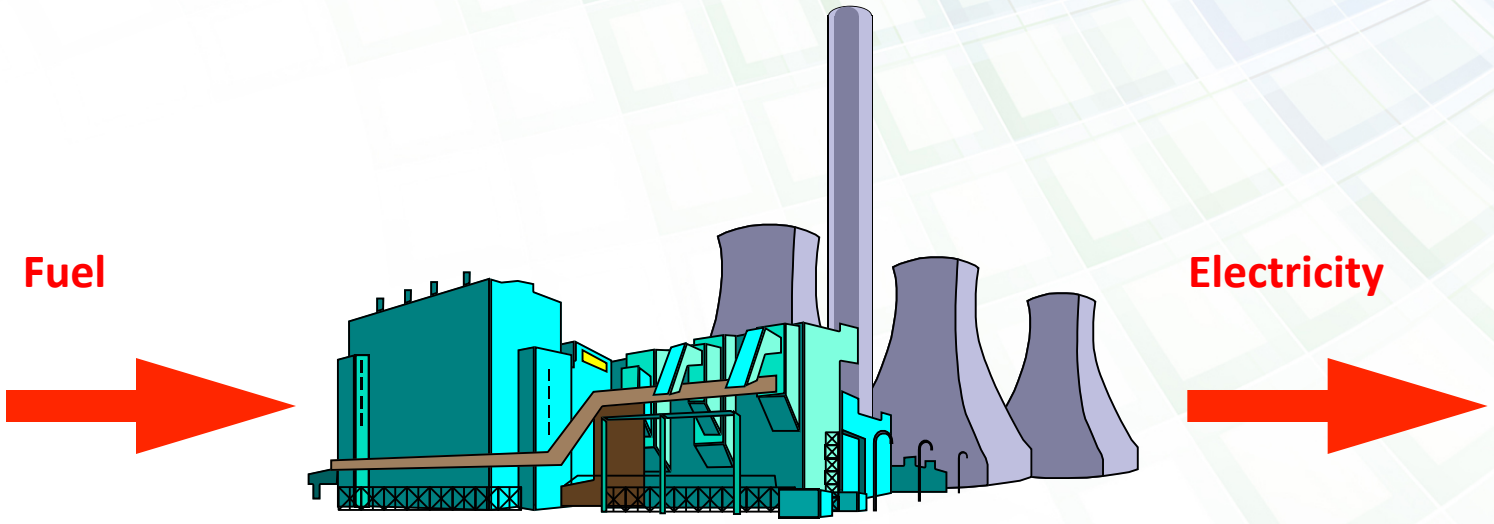


Coal



Gas

# *Secondary Energy Production is Energy That is Converted From One Form To Another*



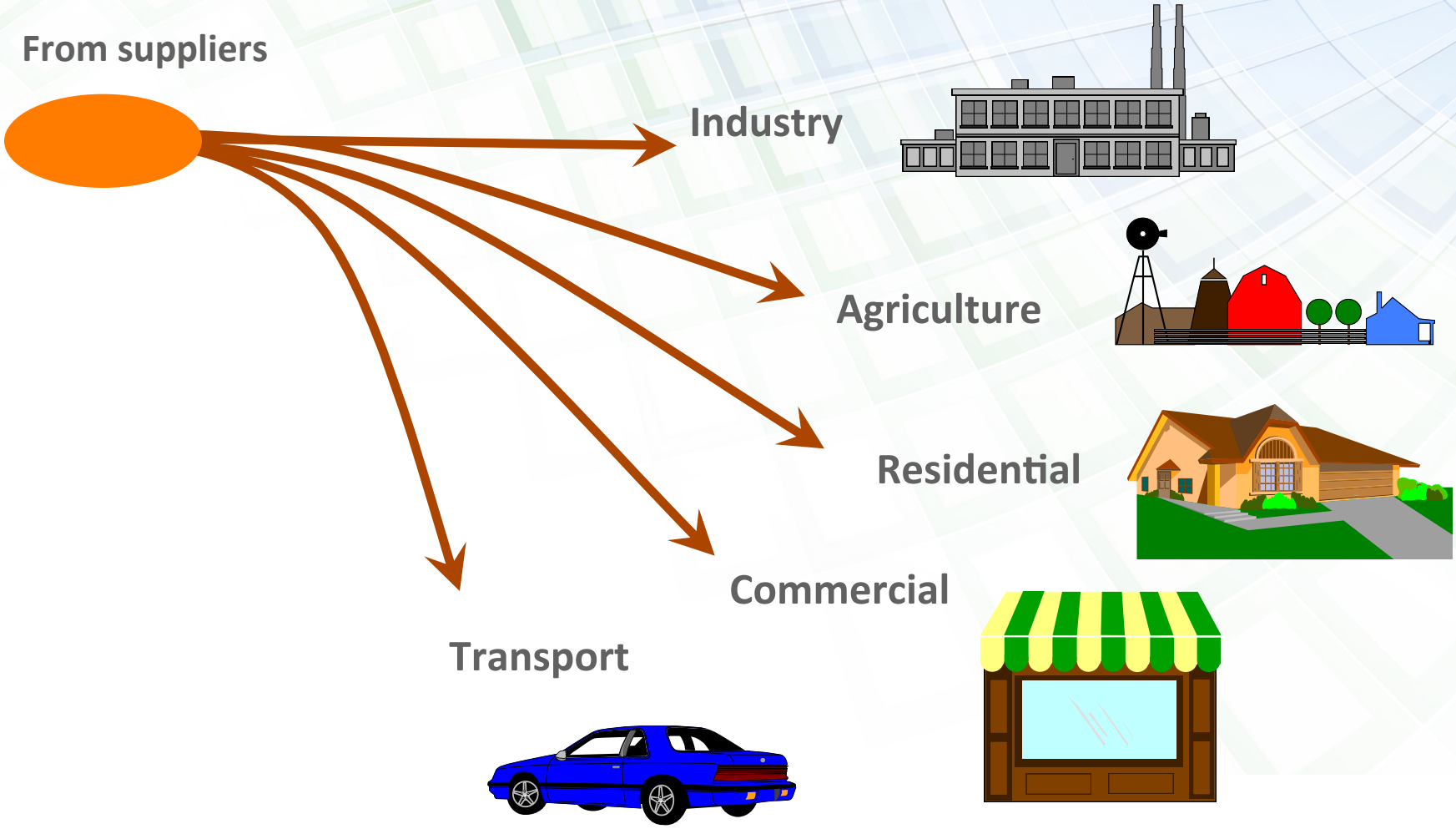
# *Energy Supply is the Energy that is Available to Users*

Kerosene
Gasoline
Fuel oil
Coal
Electricity
Wood
Charcoal
…

To Users

**Energy supply is measured at the gate of the supply facility (refinery, power plant, etc)**

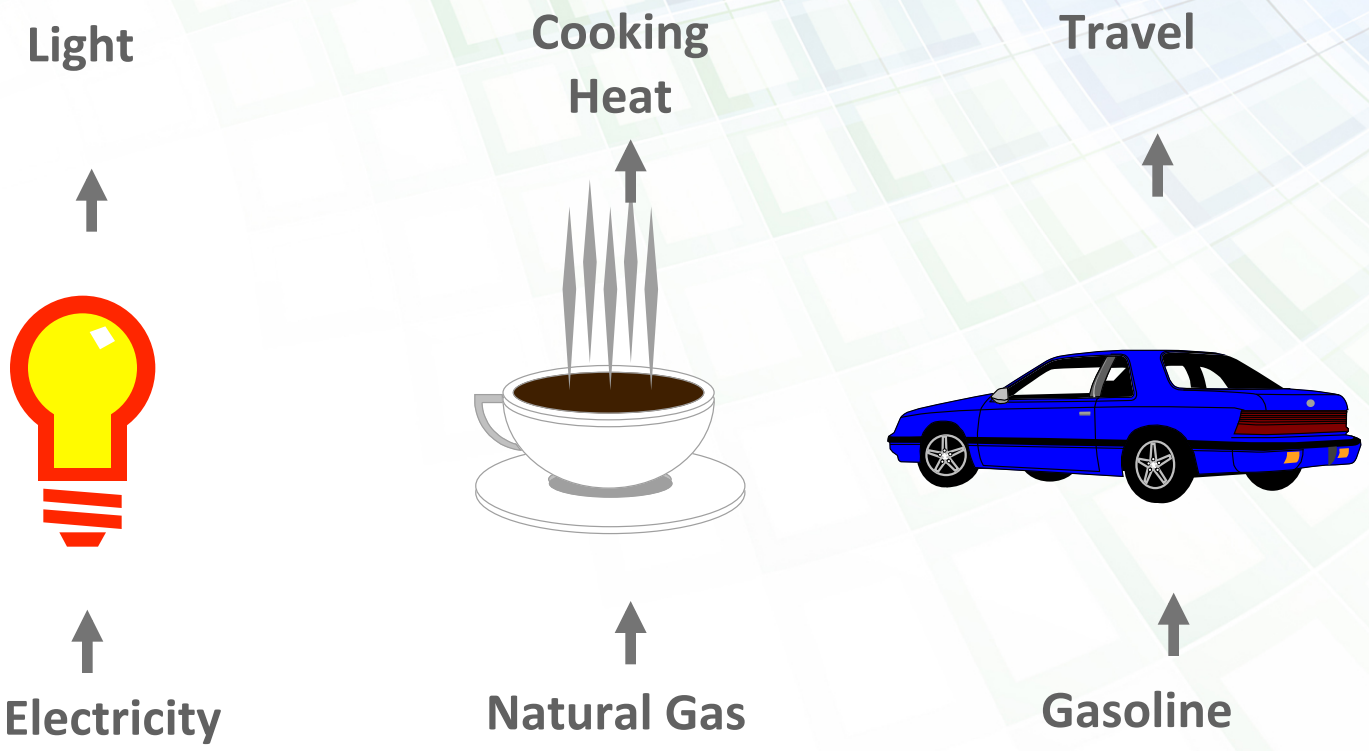
# *Energy Consumption is The Energy Purchased by Users*



# *Energy Supply and Energy Consumption are Not Always the Same*

- Transportation and transmission losses
- Excess production
- Consumption from stockpiles

# *Useful Energy Demand is the Energy Service that the User Receives*



# *The Term Energy Demand Can Be Used to Mean:*

- Final Energy Consumption

OR

- Useful Energy Demand

**It is important to know which meaning is being used**

# *The Units Used to Measure Energy Are of Two Types:*

- Physical Units
- Energy Units

# *Physical Energy Units Are:*

- tonnes of coal
- barrels of oil
- cubic meters of natural gas
- tonnes of wood
- liters of gasoline
- etc

# *Energy Units Describe the Available Energy*

- Joules (J)
- kilocalories (kcal)
- British thermal units (Btu)
- kilowatt-hours (kWh)

**These are the scientific energy units**

# *The Conversion Factors Are:*

- 1 Gigajoule (GJ) = $10^9$ Joules (J)
- 1 kilocalorie (kCal) = 4187 J
- 1 British thermal unit (Btu) = 1055 J
- 1 kilowatt-hour (kWh) = $3.6 \times 10^6$ J

# *In Addition Some Commercial Energy Units are Frequently Used*

- Barrels of oil equivalent (BOE)
- Tonnes of oil equivalent (TOE)
- Tonnes of coal equivalent (TCE)

**These are not universally defined.**

# *Some Conversion Factors Are:*

- 1 BOE = 5.7 - 5.9 GJ [ $10^9$ Joules ]
  - 5.74 is frequently used
- 1 TOE = 41 - 43 GJ
  - 41.87 is frequently used
- 1 TCE = 27 - 31 GJ
  - 29.31 is frequently used

**Note that these values vary from place to place**

# *The "Energy Content" or "Heating Value" of a Fuel is the Amount of Energy Per Physical Unit*

- GJ / tonne
- kcal / kg
- Btu / m3
- etc

# *The Best Way to Begin the Analysis is to Develop an Energy Network*

- To trace the flow of energy

- To track changes in energy prices

# *The Nodes Represent Specific Energy Activities*

- Coal mining
- Oil production
- Oil refining
- Electricity generation
- Market allocation
- Energy pricing
- Demand

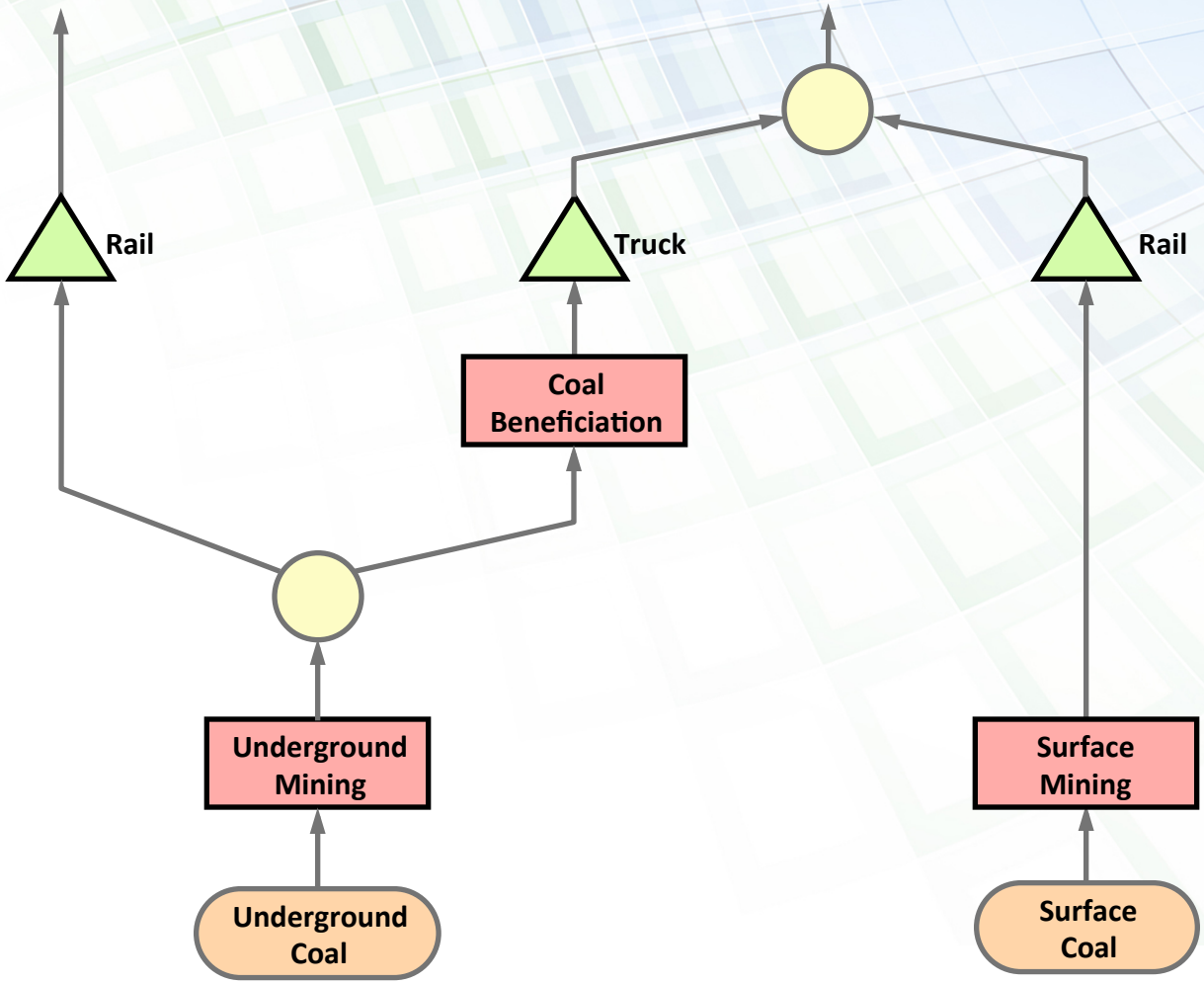
# *In Drawing an Energy Network*

- All pathways must be shown from resource to end use
- Current and future systems/resources/technologies must be included
- Detailed plant-by-plant representation can be used
- Aggregate representation by facility category can be used
- National level of detail can be applied
- Regional or local representation can be applied

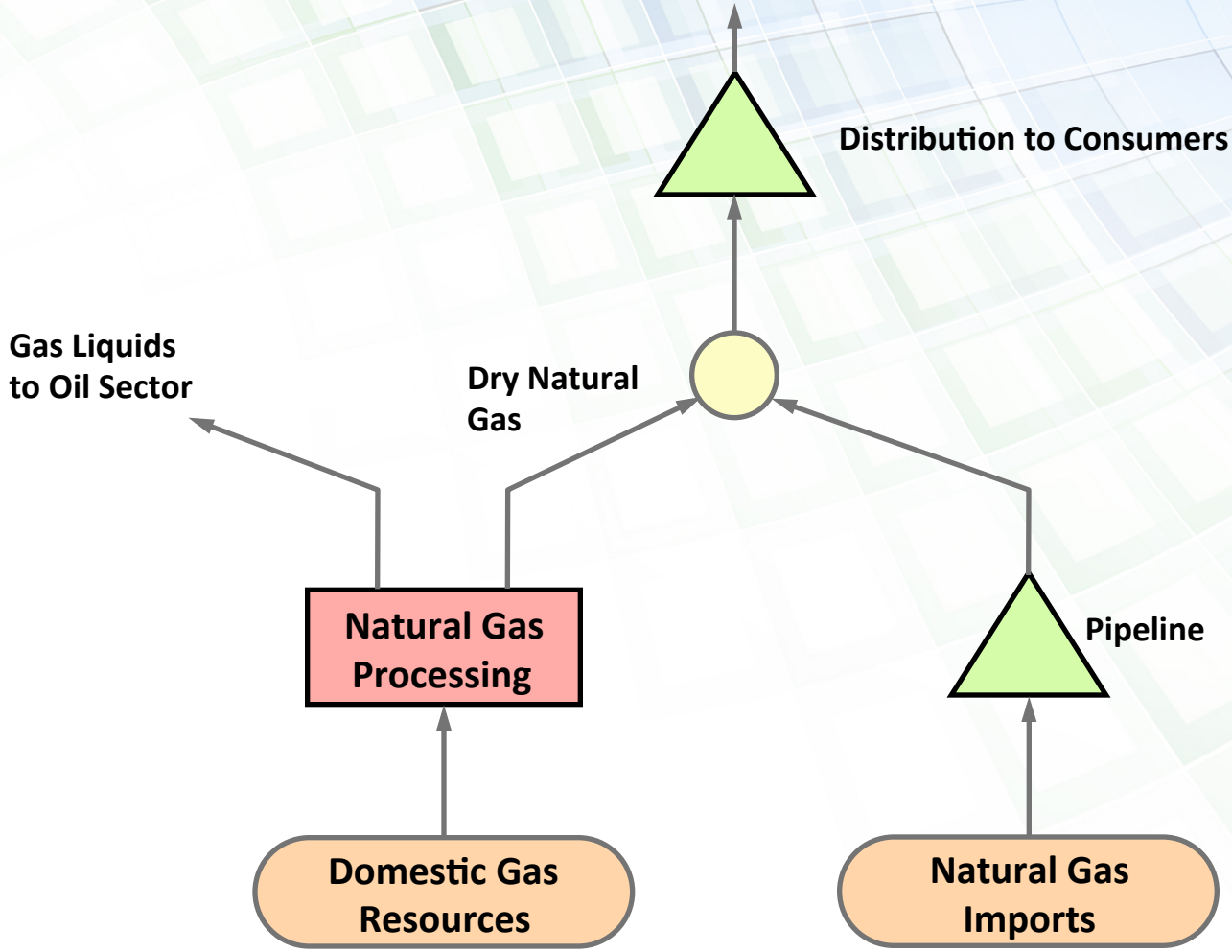
# *Once the Network is Drawn, a Consistent Data Set Must be Assembled for Each Node*

- Engineering performance data
- Economic data
- Environmental data
- Other data

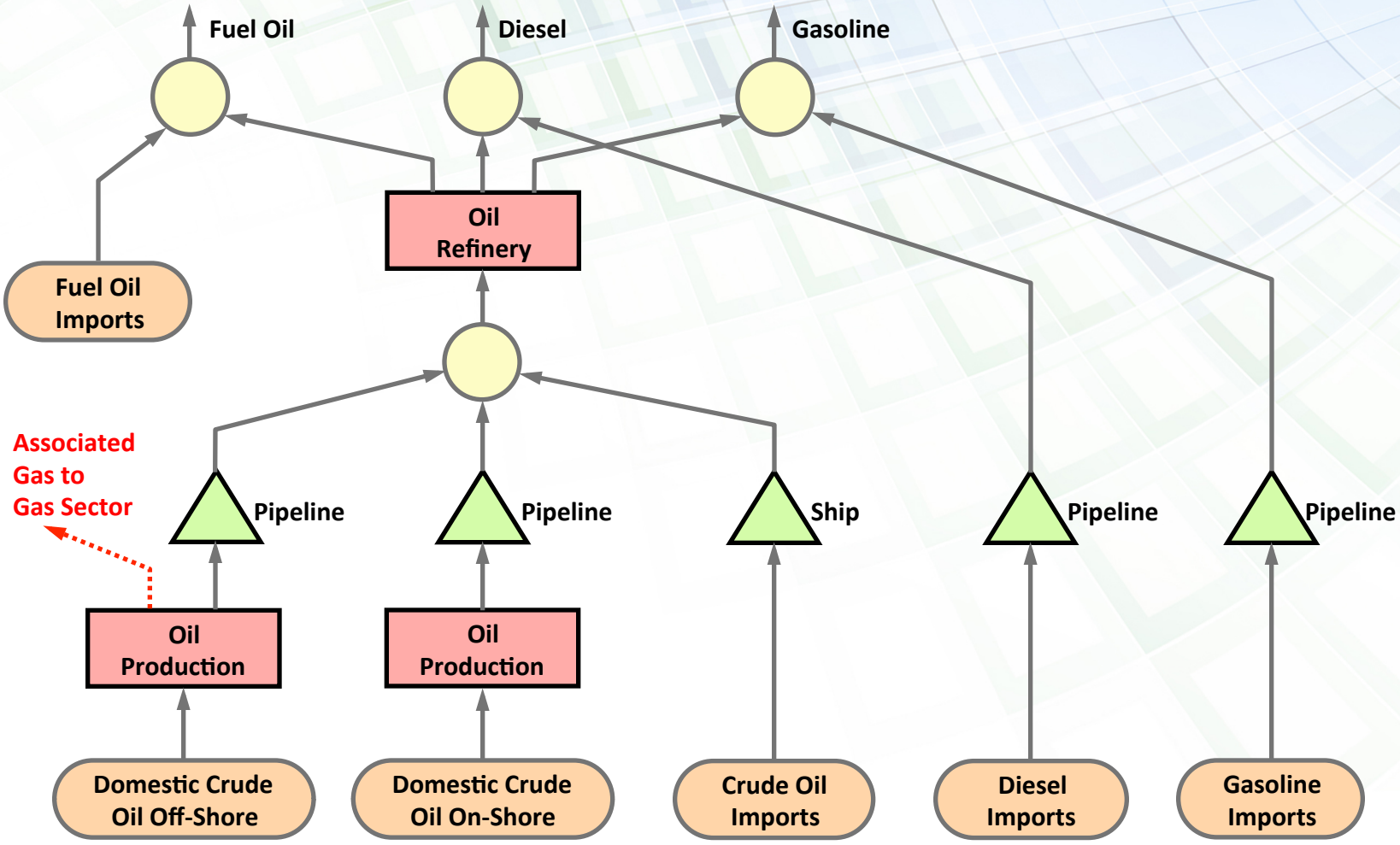
# Structure of a Simple Coal Supply Sector



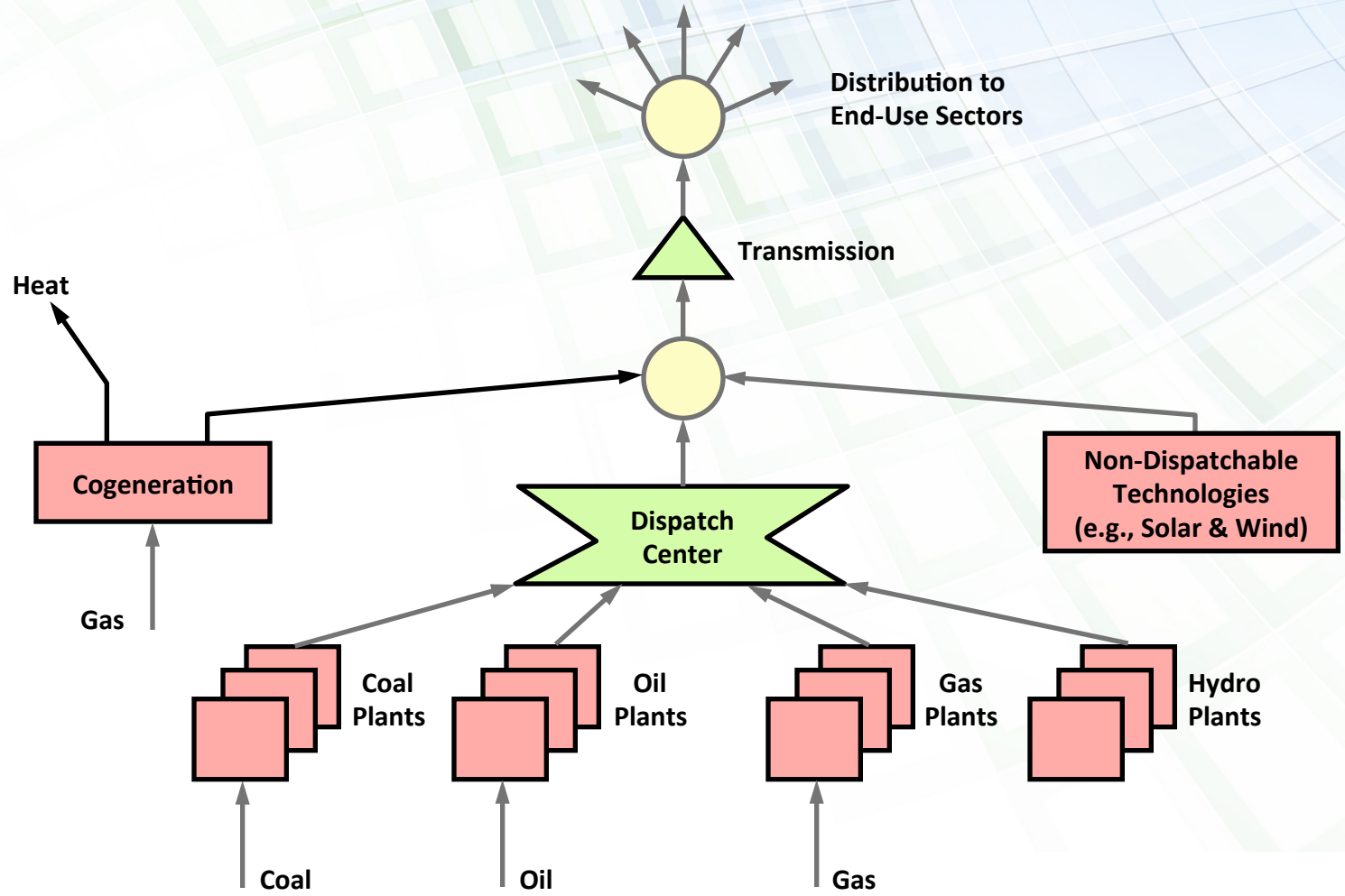
# Structure of a Simple Gas Supply Sector



# Structure of a Simple Oil Supply Sector



# Structure of a Simple Electricity Supply Sector



# NETWORK DESIGN TIPS AND COMMON MISTAKES

# Network Design Tips and Common Mistakes

- Start drawing the network first on paper (rough sketch by hand or in PowerPoint)
- Select the BASE YEAR based on the latest complete statistics available for your country (2008 or 2009)
  - Write the energy flows onto the paper version of your network
  - Make sure energy flows are CONSISTENT across the network
  - Make sure energy flows are consistent with the input data for the nodes
    - If you have a flow of 10,000 kboe on an input link into a process, the "Capacity of All Plants" of this process CANNOT be 5,000 kboe
- After the review, you should be ready to start entering your real networks into the BALANCE model
- The REFINERY, ELECTRICITY, and COGENERATION sectors are typically the most complex sectors and most likely to be the source of errors and warning messages

# Network Design Tips and Common Mistakes

- Try NOT to change the base year once you entered your input data, especially DO NOT change it during the workshop

- ENPEP-BALANCE allows to change the base year, but if you do, you will need to review and confirm all input data

- EXAMPLE: If you change the base year from 2008 to 2009, most input data is lost (inputs are entered and stored in the database for the base year; and in this case, 2008 data will be gone). If you need to do this, make sure you FIRST copy the input data for each node to the new base year

- EXAMPLE: If you change the base year from 2008 to 2005, you do not lose data, but the values are still stored for 2008 and NOT for 2005. You will have to manually enter the data from 2008 to 2005

# Network Design Tips and Common Mistakes

- Select the UNITS for energy flows, prices, costs, and emissions NOW 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 user unit divided by default 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
  User unit name: DM1000
  Unit conversion factor: 0.554

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

- Example: Default unit is kBOE
  User unit name is ktoe
  Unit conversion factor: 7.3

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

# Network Design Tips and Common Mistakes

- NEVER interrupt the software while it is accessing (reading from or writing to) the database
  - The database will most likely become corrupted and a recovery database will be created
  - Recovery database should contain your latest changes before the crash. You may continue working with the recovered database.
- During the training course, BACKUP the database regularly
- During the training course, EXPORT your case regularly

# Network Design Tips and Common Mistakes

- For every node in the network, there are certain input variables that cannot be left BLANK or ZERO; if you do not have any data, use the values given below
- ***CONVERSION PROCESS NODE***: lifetime (30), interest rate (0.1), capacity single and all (100,000), capacity factor (1.0), efficiency (1.0)
- ***ALLOCATION NODE***: Sum of all Base Year Splits MUST add to 1.0, even if there is only one output
- ***MULTI-OUTPUT/REFINERY NODE***: lifetime (30), interest rate (0.1), capacity single and all (100,000), capacity factor (1.0), sum of all output ratios (1.0), sizing link, excess demand links
- ***ELECTRIC DISPATCH NODE***: peak fraction (0.02), reserve margin (0.15), base-year production, interest rate (0.1), minimum load (0.3), load factor (0.65), number of cells (30)
- ***ELECTRIC UNITS (THERMAL+HYDRO)***: capacity, heat rate, life expectancy, on-line date

# Base Year Calibration

- Calibration is done in three dimensions:
  - energy quantities,
  - energy prices,
  - energy related emissions.
- Calibration consists of such a selection of energy network parameters that the model reflects the real energy flows, energy prices, and energy related emissions in the base year