

Final Report and Data Documentation for US9r Multi-Region MARKAL Model Development

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Support for the Development of the
USEPA 9-Region MARKet Allocation (MARKAL) Model Database–US9r

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1. Organization, Structure and Components of US9r

1.1 Naming Conventions and Identification of Key Components

The naming conventions recommended in this section of the report are based on previous work performed by members of the IRG team for EPA-ORD to develop guidelines for imposing naming conventions on the EPA National MARKAL model (EPA-NM)¹. MARKAL employs a variety of components (commodities and technologies) to define a particular energy system, and these are depicted to MARKAL by means of a Reference Energy System (RES) diagram. The *commodities* used by MARKAL are defined as energy, material, emissions or demands, and the *technologies* are resource supply options, transformation processes, conversion plants or demand devices. Given the complexities and the large amounts of information associated with most MARKAL models, rigorous naming conventions help to organize the information, and impart at first glance some basic insight as to where in the RES a particular component belongs. The use of such a structured approach to the naming conventions will also enable full exploitation of the filtering and grouping capabilities available in ANSWER and VEDA-BE, for both handling the input data and model results. The naming conventions do however serve as guidelines and may vary slightly from the norm under certain circumstances.

Also note that in multi-region models the region index serves to segregate the information as well. However it is advantageous to have the same commodities and technologies adopt the same names in all regions. The only region specific technologies one may encounter are those technologies whose characteristics vary by region, including resource supply options, existing power plants, and possibly refineries, if they have different operating costs and/or emissions profiles in different regions.

The naming convention guidelines that are laid out in this section are intended to facilitate the development and use of US9r by organizing the RES in a logical fashion that facilitates interpretation and processing of the model data and results.

1.1.1 Demands

Consistent with good MARKAL practice and the current EPA-NM, the following demand sector designations are retained, though they do not explicitly appear in the model itself. The energy service demand names must all start with the first character of their demand sector. The full listing of the recommended breakdown of demands within each sector is provided in Section 4.

- Commercial (COM)
- Industrial (IND)
- Residential (RSD)
- Transportation (TRN)

Note that supply (SUP), upstream (UPS, refineries et al) and conversion plants (CON) may also get sector designations as part of the naming of fuels, emissions and pass-thru processes.

¹ “Guidelines for MARKAL Model Naming Conventions”, performed under Contract EPA 3C-R350-NALX and delivered in November 2003.

1.1.2 Principal Energy Carrier Core Names

The naming process starts with the selection of names for the energy carriers and materials employed in the model. The general rule is to use a three-character core name for each principal energy or material group. The specific names for energy or material carriers would then add on a two or three character descriptor to the core name. The recommended core names are listed in Table 1, which contains one recommended change for Heavy Fuel Oil (HFO) from what is currently used in EPA-NM. That group is described as both Heavy Distillate and Fuel Oil in EPA-NM, and has the core name DSH, which is too close to DSL, the core name for Diesel Fuel and Heating Oil.

Table 1: Recommended “Core” Names of Energy and Material Carriers

Resource	Core Name(s)
Biodiesel	BDL
Biomass	BIO
Coal Bed Methane	CBM
Coal	COA
Coke	COK
Compressed Natural Gas	CNG
Diesel Fuel & Heating Oil	DSL
Electricity	ELC
Ethanol	ETH
Gasoline	GSL
Geothermal	GEO
Heavy Fuel Oil	HFO
Hydropower	HYD
Jet Fuel	JTF
Kerosene	KER
Liquid Petroleum Gas	LPG
Methanol	MTH
Municipal Solid Waste	MSW
Natural Gas	NGA
Natural Gas Liquids	NGL
Nuclear Fuel	NUC
Oil	OIL
Solar	SOL
Wind	WND

The complete set of EPA-NM commodity and technology names are listed in the sector spreadsheets. The general approach to naming the many intermediate energy carriers is to add additional characters to the end of the core name during the supply (e.g., NGASUP1 natural gas supply from region 1) process to differentiate the various sources until these are eventually collected into one supply stream with the core name (e.g., NGA natural gas). These ready-to-use commodities are then differentiated into the various consumptions subgroups according to the sector designations mentioned above (e.g., CONNGA/RESNGA for gas to power plants/residential) to facilitate tracking of the end-use of the commodity.

The main modification to this rule is for the coal group, where because there are 11 supply basins, surface and underground mines, and various coal types and sulfur contents, there is too much information that needs to be imparted in the commodity names to allow all three characters of the core name to be used at all times. For the coal group, the following naming approach is used: First character C for coal, 2nd and 3rd characters for the basin of origin, 4th for the type of coal, 5th for the sulfur content, and final character for an indication of how mined (surface or underground). The coal types available to any region will be collected by type and sulfur content before being made available to conversion technologies. *(If power sector mercury emissions are to be modeled, then an additional breakout for different mercury levels in coal types will be required. See Section 3 for more discussion.)* See Table 7 in Section 2.1 for a list of the various basins, coal types, and sulfur designations.

1.1.3 Resource Technologies

In US9r the fossil and nuclear resources are defined in a “dummy” supply region (Region 0, or “R0”) from which they can be exported to any of the 9 demand regions (R1 to R9). Renewable resources are depicted solely within each of the R1 to R9 regions, as they are sourced locally.

For each region into which a commodity may flow there is an export technology in R0 linked to each associated import technology in regions R1 - R9. The rules for naming the resource technologies in both R0 and the demand regions are described in detail in Section 2.

One lingering MARKAL convention that should be adhered to is that the OUT(ENT)r produced commodity and INP(ENT)x export commodity should have the same name as the 4-9 characters of the SRCENCP resource option name.

1.1.4 Conversion, Process and Demand Technology Names

Given that a maximum of ten characters are available for technology names, this naming convention subdivides the character space into specific components that are based on the names of the primary energy carriers, sector being serviced (conversion and demand) and other functions that will be described below.

The following technology names are defined to help further organize the RES and to allow the user to quickly determine the general function of a process from the technology name.

- A/C/I/N/R/T (demand devices) = the agriculture²/commercial/industrial/non-energy/residential/transportation.
- E (electricity and coupled production) = Conversion plants that produce electricity, and possibly heat.
- H (heat production) = Conversion plants that produce only heat.
- P (Transformation) = Processes that transform an energy or material through a physical, chemical or other type operation.
- SC (Collector) = Processes that collect energy (or material) carriers from multiple sources to provide a single supply to downstream technologies. Such processes are

² For US9r, it is recommended that agricultural energy use be included in the Other Industry demand sector, which is consistent with the NEMS breakdown.

called “dummy” processes, and their main purpose is to change the names of like commodities. Therefore, they usually have no associated price or technical implications. Sometimes, X, SA or SR processes can double as “collector” processes.

- SE (Emission Accounting) = Processes that are used to characterize the emissions from a particular energy carrier stream.
- SR (Emission Reduction) = Processes that are used to characterize the emission reductions from a particular technology option.
- X (transportation and upstream infrastructure) = transportation, handling, storage or other infrastructure that limits the amount of an energy carrier that can be imported or traded between two regions.

The naming convention for process, conversion and demand technologies is summarized in Table 2. To further standardize the naming process, it is also useful to prepare a list of standard designators for the resource technologies, energy carriers, process and conversion technology end-use applications and demand technologies. An example list of such designators is shown in Table 3.

Table 2: Recommended Naming Convention for Process, Conversion and Demand Technologies

Technology Type	Designators for character sectors			
	1 st character	2 nd to 4 th characters	Next 3 characters	Final 2 to 4 characters
Conversion Technologies	E for Power plants (including CHP) and H for District heating plants (no electric output)	1 to 3-character designator taken from the primary energy carrier name	1 to 3-character user-chosen descriptor (e.g., IGC, AFB) or 4-character sequencing number for existing power plants pulled from the EIA860 or NEMS database	2-character vintage corresponding to the year in which the technology is first available (00 for 2000, 05 for 2005, etc.) or <type> designator as discussed below
Process Technologies				
Transformation	P for processes that transform an energy or material through a physical, chemical or other type operation	3-character name for energy carrier	2 to 3 character abbreviation for output energy carrier or next process	2-character vintage corresponding to the year in which the technology is first available (00 for 2000, 05 for 2005, etc.) or <type> designator as discussed below
Collection	S for other supply step processes	C for collector	3-character name for energy carrier	2 or 3 character descriptor for the output energy type
Emissions Accounting	S for other supply step processes	E for emission accounting	3-character name for energy carrier	2 or 3 character descriptor for the output energy use/sector
Emissions Reduction	S for other supply step processes	R for emission reduction	1 to 3-character name for energy carrier and 2 or 3 character descriptor for the output energy use	2-character vintage corresponding to the year in which the technology is first available (00 for 2000, 05 for 2005, etc.) or <type> designator as discussed below
Transport & Upstream	X for transport & upstream infrastructure, or to “bridge” between	3-character name for energy carrier, or target sector when “bridging”	Export region number, or 3-character energy carrier name when “bridging”	E for existing (RESID) or N for New

	RES sectors			
Demand Technologies	C, I, R, T (The 1 st character of the 3-character designator for the MARKAL demand (DM) name)	2-character sub-sector descriptor (e.g., space cooling/heating = SC/SH)	2 or 3 character descriptor for the demand technology or 2-character designator used to order the list of demand technologies that service the particular demand	2-character vintage corresponding to the year in which the technology is first available (00 for 2000, 05 for 2005, etc.) or <type> designator as discussed below

For the MARKAL technologies that have several vintages of individual technology types representing improvements in efficiency or availability factor, the final 2-character string corresponds to the year in which the technology is first available (00 for 2000, 05 for 2005, etc.). For technologies where vintages are not important, the alternative approach that will be explored is to use a <type> final designator with preliminary values as follows:

- C – Current tech;
- E – Existing (used for RESID only);
- I – Improved tech;
- X – Advanced tech, and
- 1-9 - if a further designation is required.

Table 3: Examples of Commodity/Technology Name Designators Qualifiers

Commodity/Technology	Qualifiers	Description
Resource Technologies and Energy Carriers	HS	High sulfur, Surface
	HU	High sulfur Underground
	MS	Medium sulfur, Surface
	MU	Medium sulfur, Underground
	LS	Low sulfur, Surface
	LU	Low sulfur, Underground
Conversion and Process Technology End-Uses	CO	Coal Combustion
	CC	Combined cycle
	CT	Combustion Turbine
	GC	Gasification
	EP	Electric Power
	AFB	Atmospheric Fluidized Bed
	IGC	Integrated Gasification Combined Cycle
	DG	Distributed Generation
Energy Service Demands and Demand Devices (1-character sector prefix plus sub-sector designator)	SH	Space Heating
	SC	Space Cooling
	WH	Water Heating
	CK	Cooking
	AP	Appliances
	LT	Lighting
	HP	Heat Pumps
	CR	Car
	HT	Heavy Truck
	LT	Light Truck
	SV	SUV
	RL	Rail

	BS	Bus
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The names for the process, conversion and demand technologies from EPA-NM model were reviewed, and we believe that significant improvements could be made by adoption of these naming conventions for US9r. This is especially so for the demand technology names, which have only the demand sub-sector and a numeral designator (e.g., CC01 to CC80). Such names impart no context information to the user and often make it necessary to refer to an external list of technology descriptions.

1.1.5 Emission Names

The names for emission commodities in a MARKAL model generally consist of at least three characters with one or two additional characters added for sectoral breakdowns, as shown in Table 4.

Table 4: Recommended Emission Names

Commodity	Designators for Character Sectors	
	1 st to 3 rd characters	4 th up to 6 th characters
Emission	CBN = Carbon MTH = Methane NOX = Nitric oxides P10 = Particulates < 10 microns SUL = Sulfur VOC = Volatile organic compounds	1 to 3-character descriptor corresponding to the demand sector 1 st character for sector subtotals

The emission commodity names in the EPA-NM were reviewed and used as a starting point for the recommended names shown in Table 5.

Table 5: Recommended Emission Names for US9r

Emission	Description
CBNSRC	C emissions from resources
CBN	Emissions of carbon economy wide
CO	CO emissions
CBNCOM	Carbon emissions from the commercial sector
CBNELC	Carbon emissions from electricity sector
CBNIND	Carbon emissions from the industrial sector
CBNOTH	Carbon emissions prior to sector specific
CBNRES	Carbon emissions from the residential sector
CBNTRN	Carbon emissions from the transportation sector
MTHIND	Methane emissions from industrial sector
N2OIND	N2O emissions from industrial sector
NOXCOM	NOX emissions from the commercial sector
NOXELC	NOX emissions from electricity sector
NOXIND	NOX emissions from the industrial sector
NOXRES	NOX emissions from the residential sector
NOXTRN	NOX emissions from the transportation sector
P10	PM-10 PARTICULATES
P25	PM25 emissions

SULCOM	Sulfur emissions from Commercial sector
SULELC	Sulfur emissions from Electricity generation
SULIND	Sulfur emissions from Industrial sector
SULRES	Sulfur emissions from Residential sector
SULTRN	Sulfur emissions from Transportation sector
SUL	Sulfur emissions economy wide
VOC	VOLATILE ORGANIC CHEMICALS

1.1.6 User-defined Constraints

User-defined constraints are usually introduced to reflect considerations beyond the scope of the model and to avoid abrupt, unrealistic changes over time. Such constraints may be defined to control the investment, capacity or operation of a set of processes in *absolute* (noted A_*) terms (e.g. capacity of all nuclear plants) or as a *share* (noted S_*) of a larger set (e.g., percent of total electricity from that must come from renewable sources). For example, with respect to the latter, to simulate a renewable portfolio standard the modeler can easily specify that at least 5 percent of electricity generation must be from the combined output of renewable generation technologies beginning in 2010, increasing each period by an additional 2 percent. In this case, the user-defined constraint would specify the absolute proportion of the small set, which refers to generation from all renewable technologies in the RES, and the large set, which consists of the electricity output from all generation technologies (including renewable technologies).

Similarly, a share user-defined constraint might be created to control the rate change in the fuel proportions at the end-use level and to manage the rate at which new or improved technologies penetrate the market. A typical way to proceed is to define market shares in 2005 using the base year information (2000) and to apply a ‘relaxation factor’, which decreases over time, in order to allow MARKAL to be increasingly responsive to economic factors. Absolute constraints are also used to tie the capacity of two technologies, for example if a heat pump is modeled as two separate demand devices, one servicing heating the other cooling, with differing seasonal performance characteristics but investment in a single device.

The recommended approach to naming user-defined constraints is shown in Table 6, and a review of the current constraint names in EPA-NM shows that the current set of constraints³ conforms to this convention.

Table 6: Naming Convention for Used-defined Constraints

User-defined Constraint	Designators for Character Sectors			
	1 st and 2 nd characters	3 rd to 5 th characters	6 th up to 8 th characters	Final 2 characters
Absolute Share	A_ S_	1 to 3-character descriptor corresponding to <ul style="list-style-type: none"> the energy carrier involved, or the demand sub-sector(s) 	2 to 5 character descriptor for the constraint or commodity/technology involved	2-character vintage corresponding to the year in which the constraint is applied (if applicable)

³ See: US9r Model Parameters (0).xls

1.2 Description Guidelines

In addition to accessing and sorting model information (input data and case results) according to the component names, ANSWER⁴ and VEDA-BE also allows the user to access and sort information according to descriptions of the various commodities and technologies of the RES. This feature is most useful for filtering technologies. Therefore, the naming conventions also contain a series of suggestions to standardize the structure of technology descriptions to facilitate taking advantage of this feature.

The description, which is limited to 100 characters, is divided into the following seven components. For each technology type (resource, conversion, process and demand) a standard list for components 1, 3, 5 and 6 will be developed in jointly with EPA ORD so that these descriptions can be constructed in a consistent manner. Each of the 6 components after the main descriptor should be separated by periods (.).

1. Short technology descriptor, such as
 - CONV REFINERY
 - STEAM PP
 - LIGHT TRUCK
2. The year of availability, such as
 - EXISTING for all existing technologies (with RESIDs)
 - (05) for 2005
3. The category of technology, that is Conventional Fuel Vehicles (CFV) or Alternative Fuel Vehicles (AFV);
4. The main fuel consumed, such as (DSL) for diesel, sans any sector designation;
5. The efficiency that is standard (STD) or improved according to the Corporate Average Fuel Economy norms (CAFE), or some other standard;
6. Other particularities, like the size of the cars (COMPACT) or the detail of the CAFE norms, which can be standards (STD) or more efficient in terms of miles per gallon (7.0MPG), and
7. Any other descriptive information desired.

⁴ The new “TechFilter” facility added to ANSWER as part task 5 allows technology selection based upon short name/description masks, set membership, and commodity in/out. See Section 5 for a complete description.

1.3 Recommended Characterization of Energy Demand Services

The recommendations in this section for characterization of the useful energy service demands in US9r are taken directly from the report⁵ prepared to support improvement to the current EPA national MARKAL model (EPA-NM). The demand breakdowns recommended here are supported by methodologies to both validate the current demands projections against those of the Energy Information Administration (EIA) as reported in the AEO and to extend the EIA projections from 2030 to 2055.

1.3.1 Residential Sector

It is recommended that US9r retain the eight residential demand categories currently contained in EPA-NM. These categories can be derived from the fourteen energy consumption categories for residential energy use found in the AEO, and shown in Table 7.

Table 7: Mapping of US9r Residential Demand Sub-sectors to AEO Energy Use Categories

Name	Description	Includes the following AOE Demand Categories
RSC	Space Cooling	Space Cooling
RFR	Freezers	Freezers
RSH	Space Heating	Space Heating
RLT	Lighting	Lighting
RME	Miscellaneous Electric*	Color Televisions, Personal Computers, Clothes Washers, Dishwashers, Furnace Fans, 32% of Cooking, 78% of Clothes Drying & 89% of Other Uses
RMG	Miscellaneous Gas*	68% of Cooking, 22% of Clothes Drying & 11% of Other Uses
RRE	Refrigeration	Refrigeration
RWH	Water Heating	Water Heating

* Only the base year splits of Cooking, Clothes Drying and Other Uses are shown. These splits may change over time

For the residential sector, the approach to development of the regional demand projections would be analogous to the approach recently proposed for EPA-NM⁵. The regional housing populations for each housing type is multiplied by the end-use delivered energy intensity to project delivered energy consumption, and this value is multiplied by the average stock end-use device efficiency to get the energy service demand.

There are two critical steps to this approach. The first step is developing the regional housing type projections for total households, gas households and AC households. The RECS Table HC1-4a provides 2001 data for the numbers of housing units by census division and housing type. These splits can be used to create the projections of housing units for each demand region. The second step is determining the energy intensity values for each housing type and demand category. The various RECS regional energy consumption tables provide per unit energy consumption data for each census division for each end-use application, but for all housing types. *Unless better data can be found in NEMS, the ratio of energy intensity between housing types at the national level can be applied at the regional level to calculate the desired housing type*

⁵ Technical Approach to Extending Demand Projections for the USEPA-MARKAL Model, IRG report to U.S. EPA - Office of Research and Development Under GSA Contract No. CFF220, January 2006.

energy intensities. [Note: For NE12 model development, the residential demands will also be “mined” from the regional RECS information, but cross-referenced and allocated by state according to the SEDS data.]

1.3.2 Commercial Sector

It is recommended that US9r retain the thirteen commercial demand categories currently contained in EPA-NM and add one additional sub-sector (Commercial Miscellaneous – Biomass) for completeness. These 14 categories can be derived from the 10 energy consumption categories for commercial energy use found in the AEO, and shown in Table 8.

Table 8: Mapping of US9r Commercial Demand Sub-sectors to AEO Energy Use Categories

Name	Description	Includes the following AOE Demand Categories
CSC	Space Cooling	Space Cooling
COE	Computer and Office Equipment	Office Equipment (PC and non-PC)
CSH	Space Heating Services	Space Heating
CCK	Cooking Services	Cooking
CLT	Lighting Services	Lighting
CMD	Miscellaneous - Diesel	Other Uses*: 7% Diesel, 47% Electricity, 33% Natural gas, 3% LPG, 8% Residual fuel, and 3% Biomass.
CME	Miscellaneous - Electricity	
CMG	Miscellaneous - Natural gas	
CML	Miscellaneous - LPG	
CMR	Miscellaneous - Residual fuel	
CMB	Miscellaneous - Biomass	
CRS	Refrigeration Services	Refrigeration
CVS	Ventilation Services	Ventilation
CWH	Water Heating Services	Water Heating

* Only the base year splits of Other Uses are shown. These splits may change over time

For the commercial sector, the approach to development of the regional demand projections would be analogous to the approach recently proposed for EPA-NM⁵. The regional populations for each building type are multiplied by the regional building end-use delivered energy intensity values from EIA⁶ to calculate the delivered energy consumption by region and building type, which can be summed over building types to get the delivered energy consumption by region and end use. These values can be multiplied by the average stock end-use device efficiency to get the energy service demands by region.

There is one issue of concern with this approach. The 2003 CBESC data is not yet fully available, and so far it only provides building populations by type or by census division. The 1999 CBECS does provide the breakdown of building types by census division⁷, but there are data quality holes and not all the information is presented. It is possible that a complete set of

⁶ See file: Coml Building Energy Use Intensities – kintens.xls

⁷ See Table C3DIV. Consumption and Gross Energy Intensity for Sum of Major Fuels by Census Division, 1999

commercial building population data can be found in NEMS. Also, the complete 2003 CBECS is scheduled to be released sometime in early 2006, and the new release may resolve this concern. [Note: For NE12 model development, the residential demands will be “mined” from the NEMS regional commercial information, but cross-referenced and allocated by state according to the SEDS data.]

1.3.3 Transportation Sector

It is recommended that US9r retain the seven transportation demand categories currently contained in EPA-NM and add one additional category (Transportation Non-Energy Uses) to capture the lubricants and pipeline fuels categories in AEO. One category in AEO, Military Uses, is not included in the US9r transportation demand sub-sectors. Since this portion of the national energy use is not significantly impacted by energy and environmental policies, its absence is probably acceptable. One option would be to include this energy use category to the Transportation Non-Energy Uses category. This would have the benefit of maintaining the overall energy balance for calibration purposes, but its inclusion there would complicate the development of the demand projection for this category. The recommended eight demand categories can be derived from the thirteen transportation energy demand categories found in the AEO, and shown in Table 9.

Table 9: Mapping of EPA-NM Transportation Demand Sub-sectors and AEO Demand Categories

Name	Description	Includes the following AOE Demand Categories
TAS	Air transport services (billion seat miles)	Air
TBS	Bus services (billion vmt)	Bus Transportation
THT	Heavy trucks greater than 10,000 lbs (billion vmt)	Freight Trucks
TLV	Light duty vehicles (passenger & com'l) (billion vmt)	Light-Duty Vehicle Commercial Light Trucks
TRF	Freight services by rail (billion ton miles)	Rail, Freight
TRP	Passenger services by rail (billion vmt)	Rail, Passenger
TSH	Marine energy services (billion ton miles)	Shipping, Domestic Shipping, International Recreational Boats
TNE	Transportation Non-Energy Uses (PJ)	Lubricants Pipeline Fuel
		Military Use (not included)

For the transportation sector, the approach used for EPA-NM⁵ builds of the transport activity data provided in AEO Table 7. However, this table has no regional information. The support tables for transportation have regional sales data for light duty vehicles, but no other regional data. The BTSI does not appear to have any relevant regional transportation statistics. Therefore, the approaches used in the NE-MARKAL⁸ model and alternative data sources were explored.

⁸ NE-MARKAL: Adaptation of the MARKAL Modeling Framework for Application in the Northeast U.S., Prepared by Northeast States for Coordinated Air Use Management, December 2005.

For regional transport in US9r, there are two specific issues that did not exist for EPA-NM. The first is appropriately partitioning the demand between regions for transport modes that are inter-regional, and another is partitioning the emissions from the technologies that meet these inter-regional demands. Recommendations for handling these issues are discussed for each demand sub-sector.

1.3.3.1 Air transport

EIA aviation energy consumption statistics are based on the total amount of fuel (jet fuel and aviation gasoline) sold to users by state. These state fuel shares can be used to create regional shares of energy use that can be applied to the national level air passenger activity projections in Table 7 of the AEO to create regional air passenger activity projections. The methodology for projecting the demands from 2030 to 2055 is the same as recommended for EPA-NM.

Given that the regional airport related pollutants are highly connected with landing-take-off (LTO) activities, NE-MARKAL chose to represent aviation energy consumption by only the LTO portion of the travel rather than the entire journey. Consequently, the total energy consumption by the air segment is significantly lower than EIA estimates. This approach is appropriate for a state-based model, but it is not recommended for US9r, as a significant portion of air travel will be intra-regional, and the emissions accounting will be accurate for that portion of air travel.

For inter-regional air travel, apportioning the emissions from different segment of the flight (e.g. take-off, cruise and landing) to different regions was considered. However, it is not recommended because it would require developing interregional demand data (a 9x9 matrix) for air travel demand. Also, within any region, the number of take-offs will equal the number of landings, so that accounting by only the take-offs will capture most of the emissions. Finally, the cruise portion of interregional air travel emissions will be shared generally equally by all regions. While not precisely correct, this be considered as a possible future improvement, and for now, it is recommended that all the fuel-related emissions be accounted according to the departure region, which is how the fuel consumption is allocated.

1.3.3.2 Bus Service

The Transportation Energy Data Book: Edition 24–2004, Chapter 2, Energy, provides energy consumption for transit, intercity and school bus services. The transit and school bus energy use accounts for about 80% of the total energy use, and these are generally intraregional activities. Activity data is only provided for transit buses. *The approach recommended for bus service demand projections makes the following assumptions that should be confirmed or changed by EPA.*

- *It is desired to maintain bus service demand in activity units (vehicle miles).*
- *The bus technology characterizations will not differentiate between transit, school and intercity buses.*

Given these premises, the approach to regionalize the demand data is different for each bus type, but in the end, these will be rolled up to only one demand subsector.

The American Public Transportation Association⁹, *2004 Public Transportation Fact Book*, Table 100, provides transit bus activity and energy use for major metropolitan areas. As transit bus activity is concentrated in urban areas, the proposed regionalization approach is as follows.

1. Use the APTA data on major metropolitan transit bus activity (annual vehicle miles) and the metropolitan population data to calculate a per capita activity for each region.
2. Multiply the above value for each region by the total metropolitan population for the region to get the base year activity. Check the national total that is generated this way against the TEDB data and adjust the regional values as necessary.

The Federal Highway Administration¹⁰ provides registration information for school buses by state. Base year regional shares of school buses can be developed from this data and the applied to the TEDB data to generate regional energy use sub-totals. These can be converted to regional activity (vehicle miles) by dividing by the average school bus energy use intensity.

Intrastate bus service energy use can be divided between the regions according to a number of measures, but regional population share is the recommended measure. This energy use can be converted to regional activity (vehicle miles) by dividing by the average intercity bus energy use intensity.

The transit, school and intercity bus activity subtotals in each region can be added, and the growth projection for bus service demand can be extrapolated using the growth rate calculated from the AEO projections for national bus energy use. The methodology for projecting the demands from 2030 to 2055 is the same as recommended for EPA-NM.

It is recommended that emissions activity for bus service be totally allocated within each region. While this is not precisely correct for the intercity bus service portion of the demand, that is only 20% of the energy use, and it should be spread relatively uniformly, so this approximation should be acceptable.

1.3.3.3 Heavy Trucks

The Federal Highway Administration provides registration information for a variety of private and commercial truck types by state. Base year regional shares of heavy trucks can be developed from this data and the applied to the national level activity (vehicle miles) data in AEO Table 7 to generate projections for regional activity sub-totals. The methodology for projecting the demands from 2030 to 2055 is the same as recommended for EPA-NM.

It is recommended that emissions activity for heavy trucks be totally allocated within each region. While this is not precisely correct, the inter-regional heavy truck emissions should be spread relatively uniformly, so this approximation should be acceptable.

1.3.3.4 Light Duty Vehicles

The Federal Highway Administration provides registration information for a variety of private, commercial and public automobiles by state. Base year regional shares of light duty vehicles can be developed from this data and the applied to the national level base year activity (vehicle miles) data in AEO Table 7. Tables 36 to 45 of the AEO provide sales projections for light duty vehicles by census division and the total US. This data could be used to develop relative light

⁹ www.apta.com

¹⁰ <http://www.fhwa.dot.gov/ohim/hs00>

duty vehicle growth rates for each US9r region that could be applied to the regional base year activity to generate projections for regional activity sub-totals. The methodology for projecting the demands from 2030 to 2055 is the same as recommended for EPA-NM.

It is recommended that emissions activity for light duty vehicle be totally allocated within each region, as the vast majority of light duty vehicle use is intra-regional.

1.3.3.5 Freight by Rail

The TEDB provides activity (ton-miles) and energy use (Btu) for the major (Class I) freight railroads, which accounted for 92% of the railroad industry's freight activity in 2002. It does not include the small regional and local freight railroads. It also provides a breakdown of this activity by 14 commodity groups, which are close (but not identical) to the NEMS industry sub-sectors.

The Association of American railroads¹¹ provides a variety of rail freight statistics by state, including freight tons originated, terminated and carried. The appears to be the best measure of fuel use by state, and this data can be used to create activity shares for each region that can be applied to the national rail freight activity provided in AEO Table 7. The methodology for projecting the demands from 2030 to 2055 is the same as recommended for EPA-NM.

It is recommended that emissions activity for freight by rail should be totally allocated within each region because the measure used to create the regional shares is proportional to the energy used in the region.

1.3.3.6 Passenger Rail

The Transportation Energy Data Book: Edition 24–2004, Chapter 9, Nonhighway Modes, provides both activity and energy consumption for commuter rail, Amtrak and transit rail services. The American Public Transportation Association¹², *2004 Public Transportation Fact Book*, Table 108, provides commuter rail and transit rail activity for major metropolitan areas. As passenger rail activity is concentrated in urban areas, the proposed approach to regionalize the passenger rail activity is as follows.

1. Use the APTA data on major metropolitan passenger rail activity (annual passenger miles) and the metropolitan population data to calculate a per capita passenger rail activity for each region.
2. Multiply the above value for each region by the total metropolitan population for the region to get the base year activity. Check the national total that is generated this way against the TEDB data and adjust the regional values as necessary. (The TEDB data is derived from the APTA data in this area.)
3. Use the AEO projections for national rail transportation activity to calculate a growth rate and apply this factor to each region.
4. Use the same methodology as recommended for EPA-NM to project the demands from 2030 to 2055.

¹¹ <http://www.aar.org/AboutTheIndustry/StateInformation.asp>

¹² www.apta.com

It is recommended that emissions activity for passenger rail be totally allocated within each region as the activity is entirely intra-regional except for metropolitan areas near regional borders. .

1.3.3.7 Marine Energy

The US Army Corp of Engineers Navigational Data Center¹³ provides Waterborne Commerce of the United States Waterways and Harbors according to the following four regions:

- Atlantic Coast
- Gulf Coast, Mississippi River System and Antilles
- Great Lakes
- Pacific Coast, Alaska and Hawaii

This data can be used to generate shares for the US9r regions, but the exact approach to go from these four regions to the US9r regions is still to be developed.

It is recommended that emissions activity for marine energy be totally allocated within each region. While this is not precisely correct, the marine energy emissions are relatively small, and this approximation should be acceptable.

1.3.3.8 Transportation Non-Energy

SEDS data on transportation lubricants can be used to develop shares for the transportation non-energy that can be applied to the national level energy use data in AEO Table 7 to generate projections for regional energy use sub-totals. The methodology for projecting the demands from 2030 to 2055 is the same as recommended for EPA-NM.

It is recommended that emissions activity for transportation non-energy be totally allocated within each region.

1.3.4 Industrial Sector

It is recommended that US9r use industry demand groupings that are in line with the industrial demand categories currently used in the NEMS Industrial Model, which contains data for 16 industries; 10 manufacturing industries and 6 non-manufacturing industries as shown below:

Energy-Intensive Manufacturing

- Food and Kindred Products (NAICS 311)
- Paper and Allied Products (NAICS 322)
- Bulk Chemicals (parts of NAICS 325)
- Glass and Glass Products (NAICS 3272)
- Hydraulic Cement (NAICS 32731)
- Blast Furnaces and Basic Steel Products (NAICS 331111)
- Aluminum (NAICS 3313)
- Petroleum (NAICS 32411) – not modeled, but accounted for

Non-energy-intensive manufacturing

- Metal-Based Durables (NAICS 332-336)
- Balance of Manufacturing (all remaining manufacturing NAICS)

¹³ <http://www.iwr.usace.army.mil/ndc/wesc/wesc.htm>

Non-manufacturing

- Agriculture – Crops (NAICS 111)
- Agriculture – Other (NAICS 112-115)
- Mining – Coal (NAICS 2121)
- Mining – Oil and Gas (NAICS 211)
- Mining – Other (NAICS 2122-2123)
- Construction (NAICS 233-235)

Based on the availability of this NEMS data, it is recommended that 10 industrial demand sub-sectors be defined as shown in Table 10. This data is available at the level of the 4 census regions¹⁴, and information at the 9 census division level, such as shares of residual capacity or production market shares, will be used to split this information according to the 9 demand regions in US9r. The petroleum category in NEMS provides the total energy consumption for refining. However, what US9r needs is net energy consumption for refining. In addition, as US9r will model refineries, this information would be best used to help determine the energy consumption in the US9r refining technologies. Therefore, it is not shown as one of the industry energy demand sub-sectors in Table 10.

Table 10: Industrial Sector Energy Service Demand Categories

Name	Description	Industry sub-sectors
IAP	Aluminum Production	Aluminum
ICH	Chemicals	Bulk Chemicals
IFP	Food Products	Food and Kindred Products
IGP	Glass Products	Glass and Glass Products
IHC	Hydraulic Cement	Hydraulic Cement
IIS	Iron and Steel	Blast Furnaces and Basic Steel Products
INE	Industrial Non-energy	Extracted from Bulk Chemicals and Blast Furnaces and Basic Steel Products
INM	Non-manufacturing	Agriculture, Mining and Construction
IOI	Other Industries	Metals Based Durables and Balance of Manufacturing
IPP	Pulp and Paper	Paper and Allied Products

The NEMS data provides a set of energy consumption projections for up to 14 different fuel/feedstock types and 4 main end-use categories for every industrial demand category, as shown in Table 11. For the Non-manufacturing sub-sector, only the first three end-uses are employed and there is no breakdown of the Process and Assembly category. All the other sub-sectors include the Buildings energy use and have a breakdown of the Process and Assembly category into specific end-uses shown in Table 12.

Table 11: Industrial Sector Fuel and End-Use Categories

Fuels	Main End-Use Categories
Electricity	Process and Assembly

¹⁴ See file: NEMS Industry_regional.xls

Natural Gas	Steam and Cogeneration
Residual Oil	Electricity generation
Distillate Oil	Buildings
Coal	
Coke	
LPG	
Motor Gasoline	
Other Petroleum	
Hydropower	
Biomass-Wood	
Biomass-Black Liquor	
MSW	
Petrochemical Feedstock	

Table 12: Industrial Sector Process and Assembly End-Use Sub-Categories

Food, Bulk Chemicals and Other	Paper	Glass	Cement	Steel	Aluminum
Heat	Wood Preparation	Preparation Virgin	Grind & Crush	Coke Ovens	Alumina Production
Refrigeration	Waste Pulping	Preparation Recycled	Dry Process	Blast Furnaces	Primary Smelting
Machine Drive	Mechanical Pulping	Melting Virgin	Wet Process	Electric Arc Furnace	Secondary Smelting
Electro-chemical	Chemical Pulping	Melting Recycled	Steam	Ingot Casting	Sheet Fabrication
Other	Kraft Pulping	Forming		Continuous Casting	Other Fabrication
Feedstock	Bleaching	Post Forming		Cold Rolling	Steam
Steam	Paper/Board Making	Steam		Hot Rolling	
	Steam			Steam	

The data in NEMS would support modeling of the Industrial sector at the level of detail shown in Table 12. However, given that the focus of EPA's Air Quality Assessment (AQA) is the transportation and electricity generation sectors, this is not recommended.

The recommended breakdown of the Industrial sector energy use would use follow the approach used to model the industrial demands for EPA-NM¹⁵ in that all industry demands are mapped into general end-use categories of steam boilers, process heat, machine drive, electro-chemical and other uses using MECS data. The end-use technologies supplying each of the end-use categories are defined by fuel type and are tied together by ADRATIOS that start at the current fuel share but relax over time to allow fuel switching to occur. However, there are some differences. In particular, all the energy demands are in units of petajoules. Although NEMS

¹⁵ EPA - US National Model Industrial Module from SAGE Model, see files: EPA-NM_Industry-SAGE3.doc and USA_IND_V1P7_0601.xls.

does provide physical output quantities for aluminum, cement, glass, paper and steel, it is not clear that there is value in defining these demands in these units. However, this data can be used to calculate energy intensity per unit of physical output for these sub-sectors, which can be used in the extension of the demand values beyond the NEMS horizon.

Figure 1 describes the process to buildup of the industrial final energy use, base-year service demands and residual capacities. The analysis starts with the use of the NEMS final energy consumption data in the NEMS regional industrial tables¹⁶.

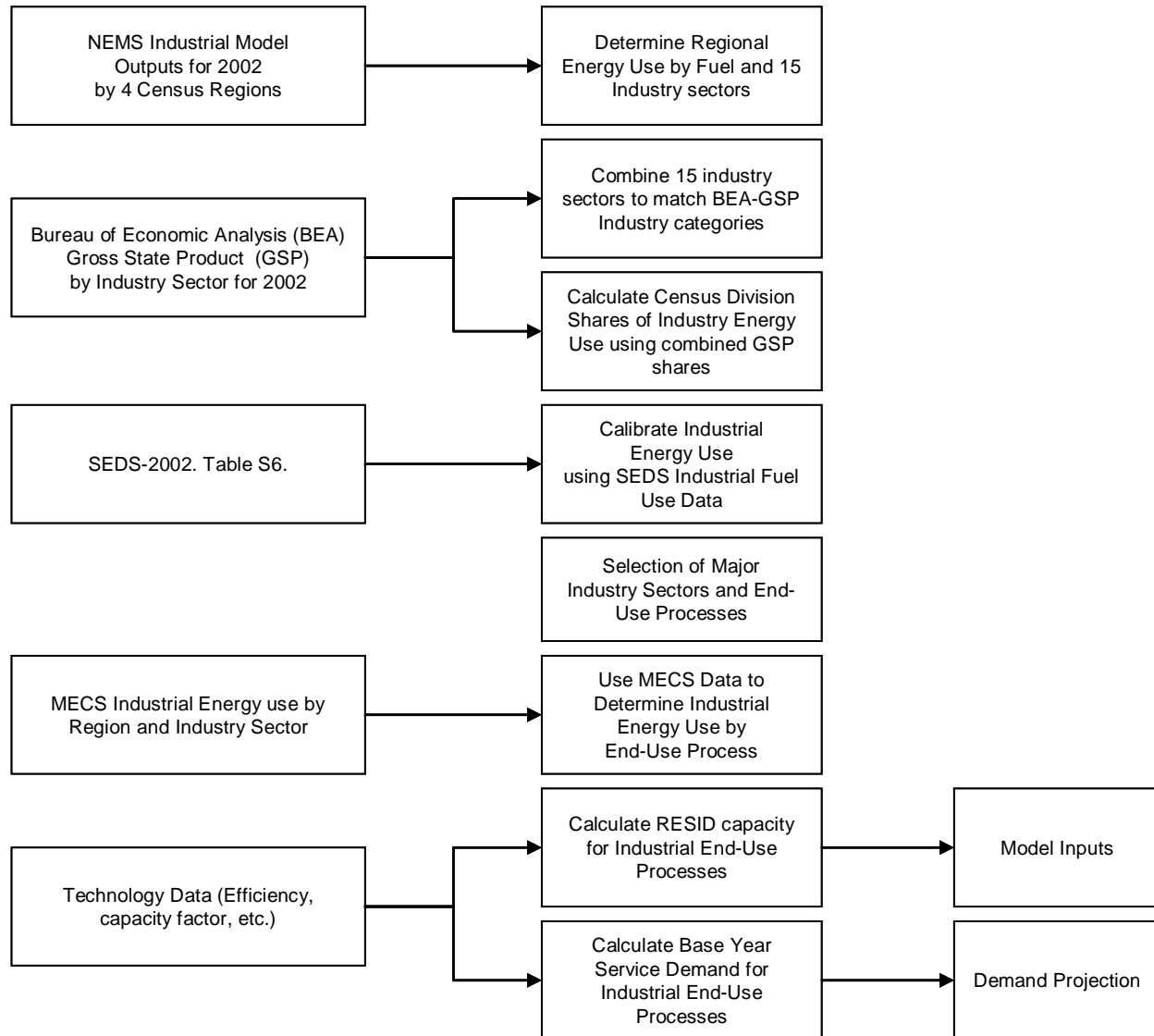


Figure 1: Industrial Sector Demand & End-Use Modeling

¹⁶ See file: NEMS Industry_regional.xls

This data is provided at the 4 census region level, and can be separated into the US9r region shares by using the data from the Bureau of Economic Analysis, which provides gross state product for a large number of industries by NIACS code. These regional energy use values are then calibrated to the final energy use numbers provided in the SEDS, which can be combined at the US9r region level. The MECS data, which is also provided at the census region level, can be used to develop end-use shares for each industry sector and fuel type. The base-year final energy data then can be used to determine the RESID capacity levels and the base-year service demands.

The projection of the service demands can be based on the NEMS regional industrial final energy consumption projection, which goes to 2030. The extension of the energy consumption values to 2050 can be based on specific industry sub-sector drivers, in particular, the sub-sector output per unit of GDP. The conversion of the final energy consumption to service demand would require the application of typical end-use device efficiencies for each end-use technology.

1.4 List of Accompanying Files

The following sections of the report describes the components of US9r MARKAL model that have been developed and delivered to EPA as ANSWER “smart” workbooks and MAKAL and ANSWER code modifications. For each ANSWER smart workbook, the documentation generally includes:

- An index with a summary of each sheet in the workbook;
- A figure depicting the main data sources and transformations;
- A description of the assumptions, algorithms and transformations applied to the data;
- A brief description of how to change the assumptions;
- A brief description of what is involved to update the XLS to a new AEO forecast;
- Opportunities for improvement

For ease of reference Table 13 lists all the ANSWER “smart” workbooks and other model components associated with this report.

Table 13: List of ANSWER Smart Workbooks

Report Section	Subsystem Workbook	File Name
2.1	Coal Supply and Transportation	US9r_SRC_Coal_v1.0
2.2	Petroleum and Natural Gas Supply and Transportation	US9r_SRC_Oil+Gas_v1.0
2.3	Ethanol and Biodiesel Supply and Transportation	US9r_SRC_Eth&Biod_v1.0
2.4	Renewable Energy Supplies and Technologies	US9r_SRC_Renewables_v1.0
3.1 and 3.2	Electricity Generation and Trade	US9r_TRD_Elc_v1.0
3.3	Utility Coupled Heat and Power	US9r_CHP_v1.0
3.4	Industrial Sector CHP	US9r_IND_v1.0
3.5	Refineries	US9r_Ref_v1.0

2. Resource Supply and Trade

The conceptual approach for the conventional resource supplies and upstream processes is shown in Figure 2. For coal, oil and natural gas extraction, and all imports, a “dummy” supply region (R0) is employed. For each region into which a commodity (<ent>) may flow, there is an export option in R0 (EXP<ent>r) linked to each associated import option (IMP<ent>r) in regions R1 - R9, where r = the number of the importing region. Note that the <ent> may be named differently in each region, but the ‘r’ defines a trade link and must be the same in both the import/export regions. Region R0 and these “supply links” will enable a single set of resource (mining and import) supply curve to be specified and drawn on by all the regions directly able to use a commodity. As explained later, along the import path for each commodity entering a region a transportation cost can be added and existing limitations on the supply of each resource can be specified, either directly on the “supply link” or by means of regional infrastructure and transportation processes where the expansion of the supply infrastructure capacity requires investment.

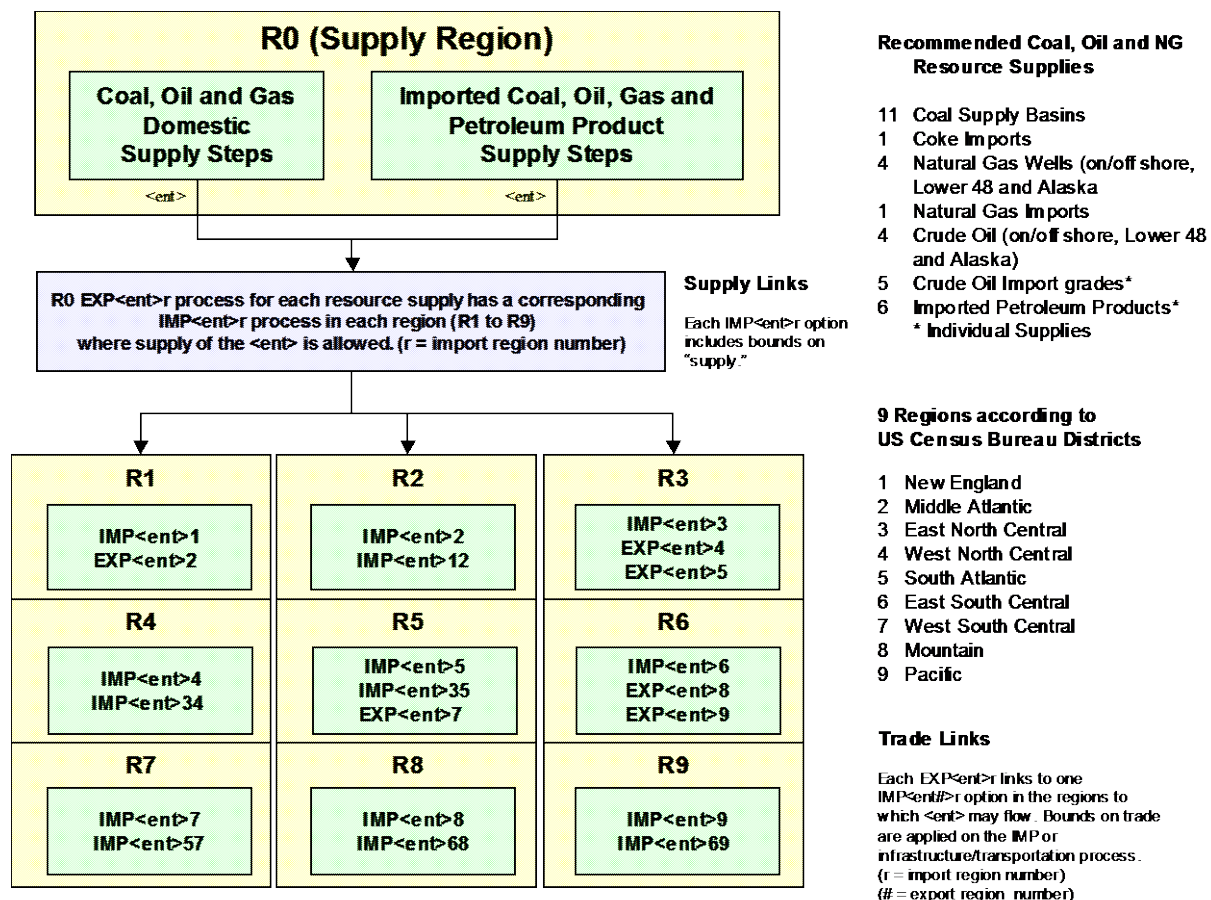


Figure 2: Conceptual Approach to Regional Resource Supply

For bi-lateral trade MARKAL requires that each EXPORT process is directly coupled with a single associated IMPORT process, as identified by as a trade route by means of the “P” of SRCENCP = IMP/EXP<ent><p>. As shown generally in Figure 3, this enables several demand regions to

draw from one resource supply region (with mining and imports), where the supply options are collected by X<ent>0 and then made available to the EXP<ent>r processes for each r=regions where the <ent> is to be consumed. Whether the X-process is needed depends on the specifics of the specific resource being modeled.

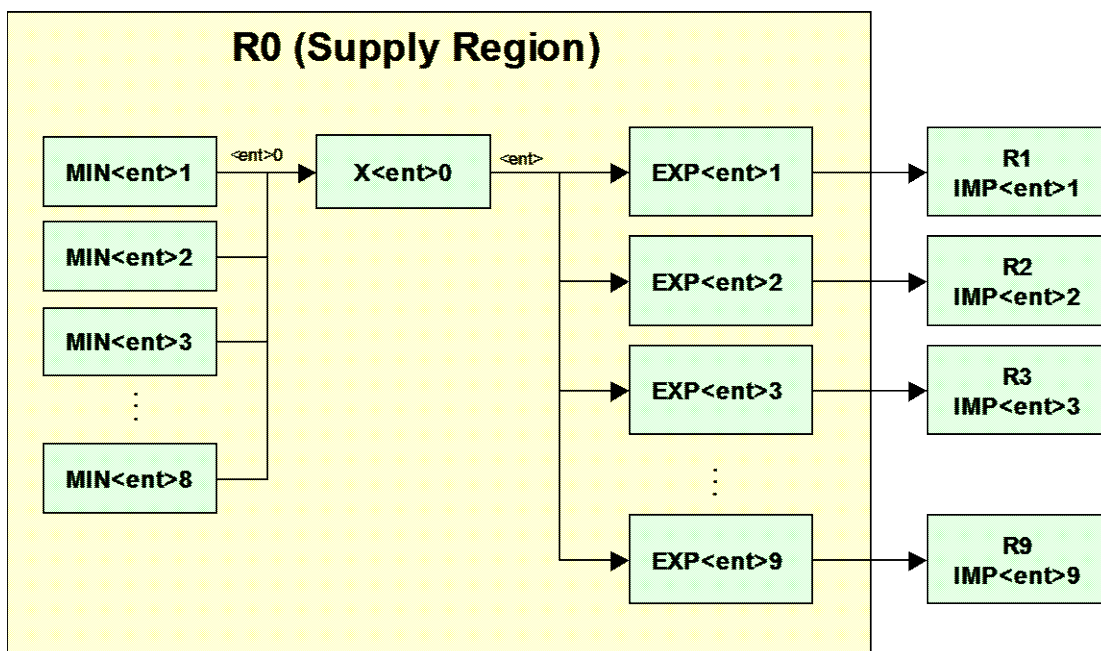


Figure 3: Mapping Resource Supply to Regional Export-Import Links

The supply and transportation approach for fossil fuels are presented, with an example, in Sections 2.1 and 2.2, followed by renewables, biodiesel and ethanol, and nuclear.

2.1 Coal Supply and Transportation

As in EPA-NM, the starting point for the coal supply sector is the set of supply step curves taken from the NEMS Coal Market Module (CMM). AEO 2006 uses 11 steps to describe coals of four ranks, three levels of sulfur content, and two mining types from 14 regions. Unlike in EPA-NM, the full level of coal characterization and regional detail has been retained, resulting in supply curves for 40 different coal types. These coals are then transported to six sectors (residential, commercial, industrial, metallurgical, coal-to-liquids, and electricity) in the nine census divisions using a matrix of transportation costs also drawn from the CMM. (Two tiers of transportation costs, representing current and expanded flows, are provided for the electricity sector.) The benefit of this approach is a significantly more accurate representation of the regional transportation-related costs of coal supply. However, the trade-off is handling a large volume of data.

2.1.1 Workbook Organization, Data Sources and Transformations

This “Smart¹⁷” workbook contains 17 worksheets as follows:

- **ANSv5_Home** – This sheet defines the Answer template region handling and version information.
- **Conv** – A list of conversion factors for use in the various data sheets.
- **Defs** – A list of definitions in the form of look-up tables for reference by formulas in the various data sheets.
- **Types** – A list of all coal types with characteristic data including energy carrier names, energy content, and sulfur and mercury contents, drawn from the CMM. In cells X2:AG6, weighted average sulfur and mercury contents for each grade/sulfur level class of coal are computed for use in electricity sector emissions calculations. The weights are the cumulative AEO 2006 production levels for each of the 40 coal types. Columns U and V also contain reserve information drawn from the Data-reserves sheet and converted into PJ.
- **Data-production** – This sheet contains annual AEO 2006 production levels for each of the 40 coal types and is used to calculate the AEO 2006 cumulative production amounts that are used in the weighted average on the Types sheet.
- **Data-curves** – The NEMS coal supply data for 40 coal basins with 11 supply steps each. Values are converted from the CMM units of 1987\$ and short tons to the US9r units of 2000\$ and PJ.
- **Data-reserves** – Coal basin reserve data from the EIA Coal Reserves Data Base (EIRRSV97.DBF). Two adjustments were necessary to use this data to develop CUM data for the CMM coal types. First, the Reserves Data Base data is by state, whereas in the CMM, some states contain more than one coal supply region. Reserves Data Base entries were assigned to states based on sulfur and rank information shown column A. Where one entry needed to be assigned to more than one region, half the reserves value was assigned each region, with the exception of the Wyoming regions, which widely differ in production volumes, where the AEO 2006 cumulative production values were used to make the splits. Second, entries were assigned to CMM coal types based on rank and sulfur content. Some entries did not match CMM coal types. Matching entries are bolded, and non-matching entries are not. For example, on Row 5, there are Northern and Central Appalachian high and medium sulfur bituminous surface coals in the CMM, but not low sulfur. In calculating total reserves for a region, two options have been presented, the total of just the matching entries, and the total with adjacent sulfur categories included. (For example, see Rows 24 and 25, which present alternative reserves calculations for Northern Appalachian medium sulfur bituminous surface coal.) For purposes of calculating the reserves for each coal type in Column U on the Types sheet, the larger values including adjacent sulfur categories have been used. More conservative CUM calculations could be made by linking Column U to the smaller total values instead.

¹⁷ Underlined worksheets correspond to actual load sheets handled by ANSWER by means of CheckSheet and Import from Excel.

- **Commodities** –Declaration sheet listing all coal mine types (40) and sectoral supply types (15), including dummy material commodities for the Tier 1 coal limits to the electric sector.
- **Technologies** –Declaration sheet listing all technologies for coal mine supply, export from R0, import to R1 through 9, transportation to the various use sectors and supply limits.
- **Tech Data R0** – Commodity specifications and model input data (costs, bounds and cumulative limit) for all coal supply steps. BOUND and COST data are taken from the Data-curves sheet. These are extrapolated to 2050 using the average growth rate from 2020 to 2030. CUM values calculated by sharing the Reserves value from the Types sheet across the 11 steps of each coal type according to the fractional share of the sum of the BOUNDS of each step across the model time horizon.
- **Tech Data ExIm** – Commodity specifications and bilateral trade links for all coal export/import technologies, using the matrix from the Trade-rules sheet to specify allowed and not allowed supply links.
- **Tech Data Trans** - Commodity specifications and transportation cost data, taken from the Trans-rates sheet and escalated using the Rate esc sheet, for all allowed coal transportation technologies, as determined by the coal type and sector use. Includes output materials for tracking Tier 1 coal supply to electric sector.
- **Tech Data Limits** - Commodity specifications and upper bound data, taken from the Trade-rules sheet, for limiting Tier 1 coal supply to the electric sector.
- **Trans-rates** – NEMS data on coal transportation costs for six sector use (residential/commercial, industrial steam, metallurgical, coal-to-liquids, and electricity (Tier 1 and Tier 2)).
- **Trade-rules** – Rules table developed from inspection of the Trans-rate data that specifies the coal export-import pairs that are allowed or not-allowed. Also includes the Tier 1 coal transport upper bound data from NEMS.
- **Rate esc** – NEMS data on the expected cost escalation for transportation of eastern and western coals, used as in the CMM to project transportation costs from 2000 values.
- **Region shares** – Shares from NEMS data used to combine CMM coal demand regions that are portions of census regions.

The data flow of the various worksheets is depicted in Figure 4. Because of the size and format of the coal supply curve data, the workbook employs a variety of Excel functions for lookup, reference and text manipulation to create commodity and technology names and descriptions and to correctly determine the proper parameters for each specific coal type. The look-up definitions are contained in the Defs sheet, and the coal type properties and other parameters are contained in the Types sheet for lookup reference.

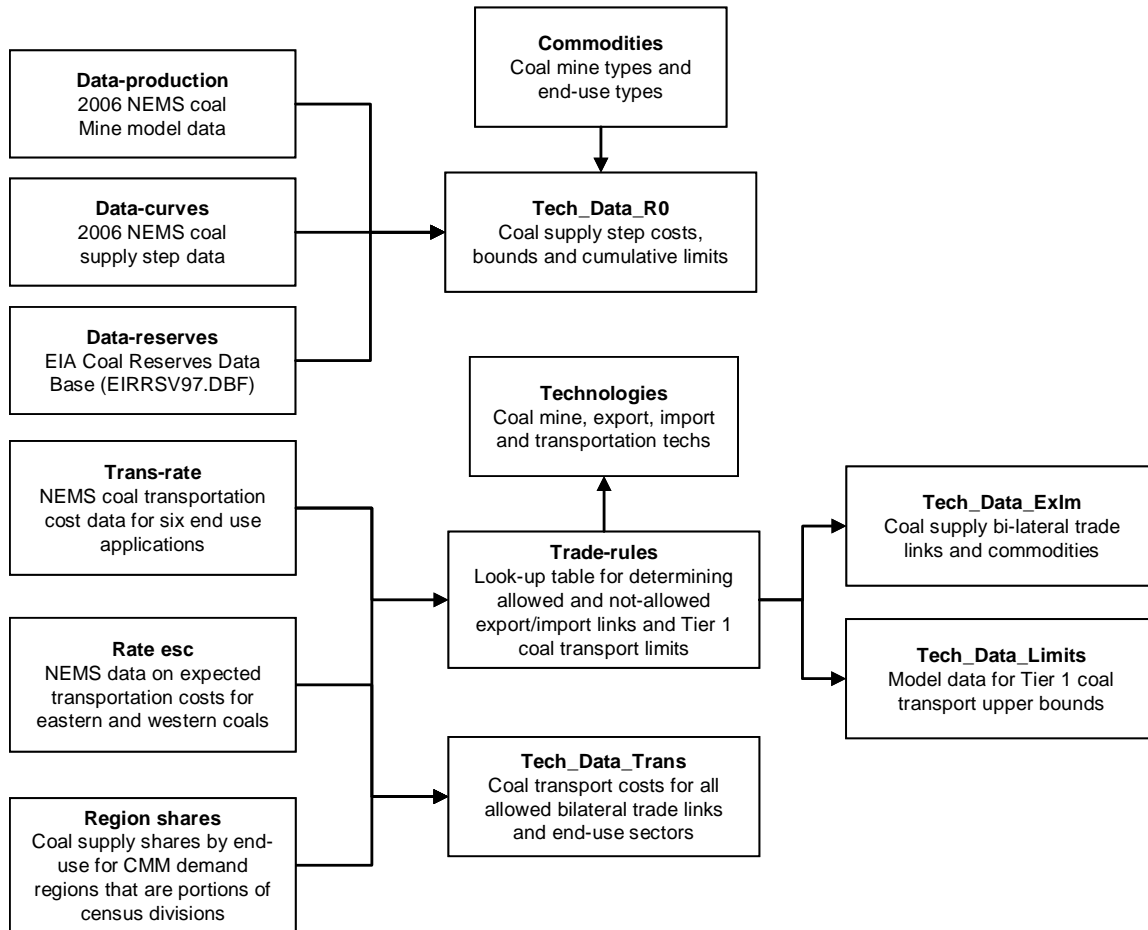


Figure 4: Coal Supply Workbook Data Flow

2.1.2 Coal RES and Trade Structure

The data from the 2006 Coal Mine Model (CMM) and from the EIA Coal Reserves Data Base supplies the costs, bounds and cumulative limits for the 40 coal supply basins, each having 11 coal supply steps. Because of the current limitation of commodity and technology names to 10 characters, these supply steps were named A thru K, as shown in Figure 5. This figure also shows that each coal type requires one export process that is linked to a corresponding import process in the supply region, and the import region number is appended to the name of the export and import process names to establish the trade route. As a result, there are 360 (40x9) possible export-import pairs, but not all coal types can supply all regions, and the Trade rules table is used to identify allowed and not-allowed links. The not-allowed links have an “* Not allowed” indicator in column A of the Tech_Data_Trans worksheet, which ANSWER interprets as a comment as ignores the technology definition for that row. The Trade rules table was constructed manually from a careful scan of the Trans-rates data file.

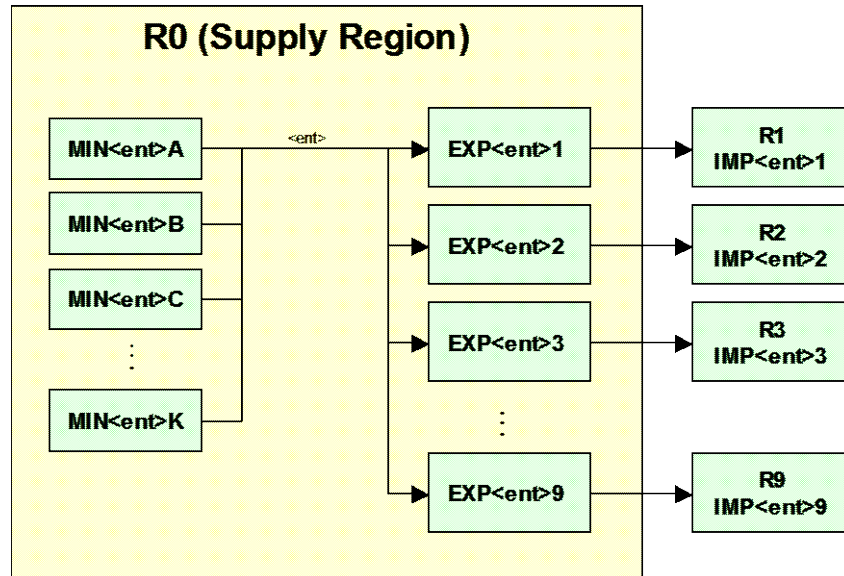


Figure 5: Supply Export and Import Technology Structure

Coal supply to each region and transportation to the various end-use applications is shown in Figure 6 for the Southern Appalachian bituminous high sulfur underground coal (CSABHU). For each region where coal supply from this type is allowed, owing to sector price differentials, there are seven transportation processes, as the data for residential/commercial must be split into two processes with identical transportation costs. The Trans-rates file identifies not-allowed (or not currently used) transportation links with an entry of 999.99, and this indicator is used to place “* Not allowed” in column A for the data entry row relating to such links. In this manner, the data entry for the Tech_Data_Trans worksheet was relatively automated, with the exception that regions 3, 5, 6 and 8 have divided demand regions in the CMM, and the CMM shares needed to be applied to the transportation cost.

For electricity end-uses, Tier 1 represents the current transportation links, and Tier 2 the possible expansion of those links. So Tier 1 needs to have a limit on it, corresponding to existing capacity, and Tier 2 an investment cost to be applied in addition to the transport cost. To model the Tier 1 limits, a dummy material commodity was introduced for each coal supply basin and demand region where coal goes to the electric sector. In each demand region, the Tier 1 X-process for all coal types (HS, MS, etc) from a particular supply basin are collected and a single process that contains the transport upper bound. Once that limit is reached, the model must use the Tier 2 X-process to supply more coal to that region’s electric sector. This is illustrated in Figure 6.

For the other coal end-uses, there are no transportation limits, so as much as is desired can be transported on any allowed link, with any sector transport costs applied.

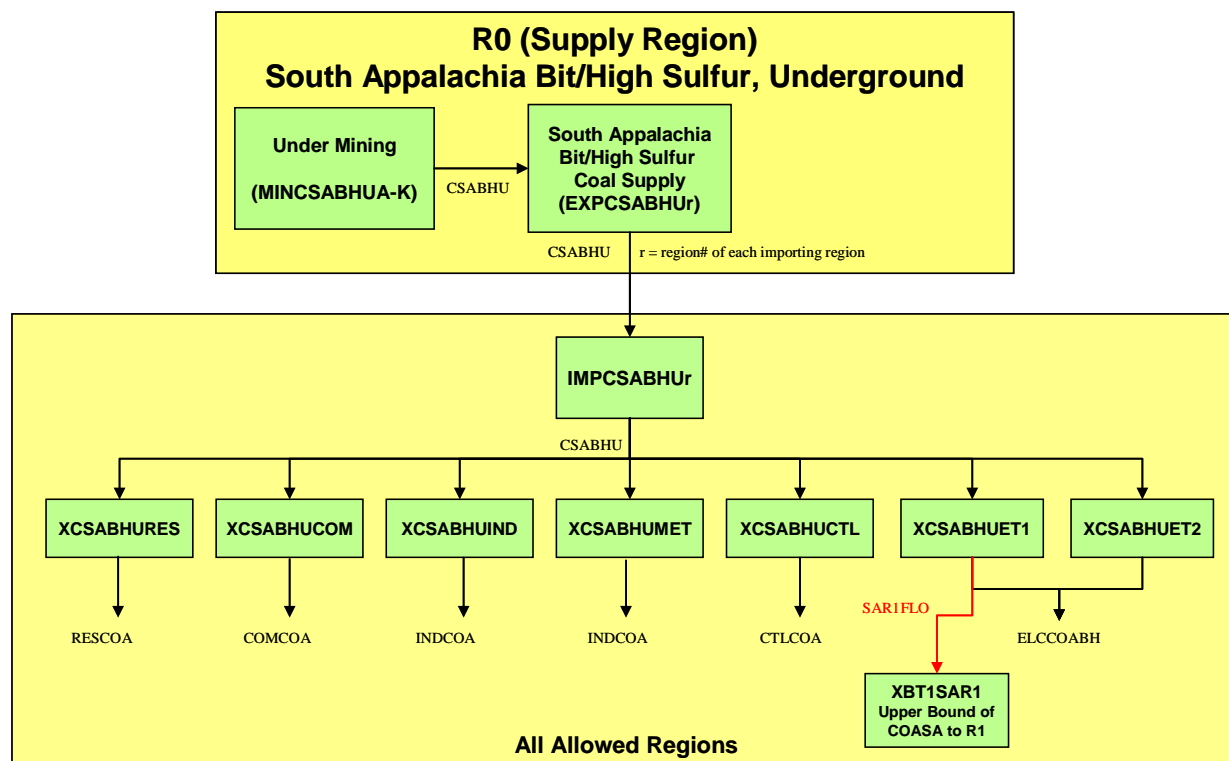


Figure 6: Coal Supply and Transportation to Sector Applications

2.1.3 Areas for Possible Modification and Improvement

The key area of potential concern and possible improvement is in the area of the allowed/not-allowed coal transportation links. Our current understanding is that the transportation cost data represents two things:

- Market conditions: The data basically represents where there are and are not existing contracts. Thus, some links may have a 999.99 because there is no active market, but the transport link may be physically possible.
- Different transport modes or routes within the same supply/demand pair that are used for different end-uses. For example surface and underground coal for a particular transport link might come from sufficiently different areas so that one transport mode will not work for both. Another example would be dedicated rail lines to power plants that might not serve industrial or commercial markets.

Therefore, the decision was taken to not combine surface and underground coals in R0 and only export coals by type and sulfur content as originally envisioned. Instead, surface and underground coals are exported separately from R0, and their different transportation costs and allowed links in each demand region to specific end-use are maintained.

For high coal demand scenarios, EPA may want to revisit the current set of allowed transportation links to see if some of the current not-allowed links could be allowed.

2.1.4 Updating the Workbook

The coal supply workbook has been constructed in a manner that should allow easy updating when new AEO forecast becomes available that EPA wishes to implement. The structure on the three key data sheets (Data-production, Data-curves and Data-reserves) preserves the original structure of the data tables, and new data can be pasted into these sheets as long as there has been no change in the table format or data structure. The other key data sheet (Trans-rates) first needs to be sorted in the following order – census region, coal supply region, coal end-use application. Then, the residential/commercial data rows need to be duplicated and designated as different types according to the lookup table in the Defs sheet. Finally, the share calculations need to be applied to regions 3, 5, 6 and 8.

2.2 Petroleum and Natural Gas Supply and Transportation

2.2.1 Workbook Organization, Data Sources and Transformations

The Oil and Natural Gas Supply Workbook contains 27 worksheets as follows:

- **ANSv5_Home** – This sheet defines the Answer template region handling and version information.
- **Resources** – Cumulative resource data from the U.S. Geological Survey World Petroleum Assessment 2000. Space is also provided for adding additional resource estimates.
- **Types** – A list of all oil and petroleum product types with characteristic data including energy carrier names and energy content.
- **prdcurv** – NEMS supply step input data for all imported petroleum products into all PADD regions.
- **crdcurv** – NEMS supply step input data for all imported crude oil types into all PADD regions.
- **Shares** – Supply shares used to apportion domestic crude, domestic natural gas and imported natural gas and LNG to model regions, calculated from NEMS output data on sheets OILDom, NGADom, and. NGATrade
- **OILDom** – AEO 2006 output Table 71. Lower 48 Crude Oil Production and Wellhead Prices by Supply Region.
- **NGADom** – AEO 2006 output Table 72. Lower 48 Natural Gas Production and Wellhead Prices by Supply Region.
- **NGAImports** – AEO 2006 output Table 76. Natural Gas Imports and Exports.
- **Intl CUM** – Worksheet for calculating allowed cumulative values for all resource supply steps.
- **Commodities** – Domestic natural gas, domestic and imported crude oil and imported petroleum product types.
- **Technologies** – Technologies for domestic oil and natural gas supply, and imports of crude oil and refined petroleum products into each PADD supply region.

- **Tech Data R0** – Commodity specifications and model input data (costs, bounds and cumulative limit) for the domestic oil and natural gas supply steps and the imported crude oil and refined petroleum products supply steps.
- **TechData ExIm** – Commodity specifications and model input data (output shares and bilateral trade links) for all oil and natural gas supply, import and trade processes.
- **TechData DelOIL** – Commodity specifications and model input data (delivery costs to 24 end-use sub-sectors) for refined oil products from refineries, trade by pipeline and trade by barge/vessel.
- **TechData DelNGA** – Commodity specifications and model input data (delivery costs to the 5 end-use sectors) for domestic, imported and traded natural gas.
- **TechData Limits** – Commodity specifications and model input data (upper bounds and investment costs-where applicable) for pipeline transport of refined oil products. A dummy material commodity is used to sum across all refined products that can use a common pipeline.
- **Scenario Gen** – the Set-up sheet for defining parameters to establish various resource supply scenarios. Also contains a matrix of transport costs for pipeline and barge transport of refined oil products.
- **DelivOIL** – Worksheet for developing the crude oil delivery costs and the refined oil product delivery costs to the 24 end-use sub-sectors.
- **OILTrade** –Compilation o NEMS data on oil product transport costs and capacities.
- **DelivNGA** – Worksheet use to develop natural gas delivery costs to the 5 end-use sectors based on NEMS Table 78. Natural Gas Delivered Prices by End-Use Sector and Census Division.
- **NGACap** – Worksheet for developing natural gas trade link capacities based on NEMS Table 84. Natural Gas Pipeline Capacity by NGTDM Region (primary and secondary), and NEMS Table 91. Primary Natural Gas Capacity Entering NGTDM Region from Neighboring Regions.
- **NGATrade** – NEMS Table 90. Primary Natural Gas Flows Entering NGTDM Region from Neighboring Regions, and the LNG portion of NEMS Table 76. Natural Gas Imports and Exports.
- **NGExpansion** – Natural gas pipeline expansion cost data.
- **Constraints** – Definition of adratios for sharing domestic oil and natural gas supply between regions.
- **ConstrData** – Share data for the above adratios using TechItems and Ratrules.
- **Conv** – A list of conversion factors for use in the various data sheets.

Data for imported refined products and imported crude oil comes straight from the NEMS input files for 2000-2030. There are five supply steps specified for each product for each of the five PADD supply regions.

For domestic oil and natural gas, the starting point is a cumulative (CUM) amount of resource expected by USGS to be discovered over a 30 year time horizon. The resource is apportioned into 10 equal sized cost bins, with the cost steps set to bracket AEO forecast prices. A DECAY

parameter is imposed, which is intended to mimic a maximum production to reserves ratio -- all of the remaining resource cannot be used up in any forecast year. A GROWTH constraint is also imposed to keep the low cost bins from being used up early. All of these parameters are adjustable on the Scenario Gen sheet.

This approach of using a CUM and a DECAY rate has been adapted to project the out-years for imported supplies. To get the CUM, total foreign resources, multiplied by the fraction available for US consumption, are apportioned to all of the cost steps for all of the imported energy carriers. An adjustment factor is used to keep the very large step 5 values from dominating. This procedure will keep a constant ratio between the different energy carriers, which may or may not be appropriate -- so this aspect may need some adjustment. For example, it might be more appropriate to use the 2030 quantity steps, rather than the sum over the forecast horizon as the weights. As with domestic supplies, all of these factors are adjustable on the Scenario Gen sheet and can and should be adjusted during calibration and scenario analysis.

2.2.2 Crude Oil RES and Trade Structure

Crude oil is a globally traded and priced commodity. Therefore, the supply structure for oil resources and upstream processes in US9r is simpler than that for coal supply. Crude Oil Imports are defined according to the following grades by sulfur content and specific gravity, which comes from EIA data.

- Imported Oil-Low Sulfur, Low G
- Imported Oil-Medium Sulfur, HG
- Imported Oil-High Sulfur, Low G
- Imported Oil-High Sulfur, Heavy G
- Imported Oil-High Sulfur, Very HG

The refinery model in EPA-NM, which has been regionalized and updated for US9r, collects all crude oil sources without regard to sulfur content on the basis that 1) refineries typically operate with a blend of crude sources, and 2) the refineries will remove all sulfur to the limit allowed in the final petroleum products. Incremental refining costs cannot be handled in the current refinery model, but these are not considered to be very significant. These distinctions are retained for the purpose of consistency with the data source, and in consideration for possible future use.

Figure 7 illustrates the RES for imported crude. NEMS provides stepped supply curves for imports into the five PADD regions. These are all imported into R0, producing energy carriers that are labeled by PADD number which are then available for export to the Census divisions corresponding to each PADD.

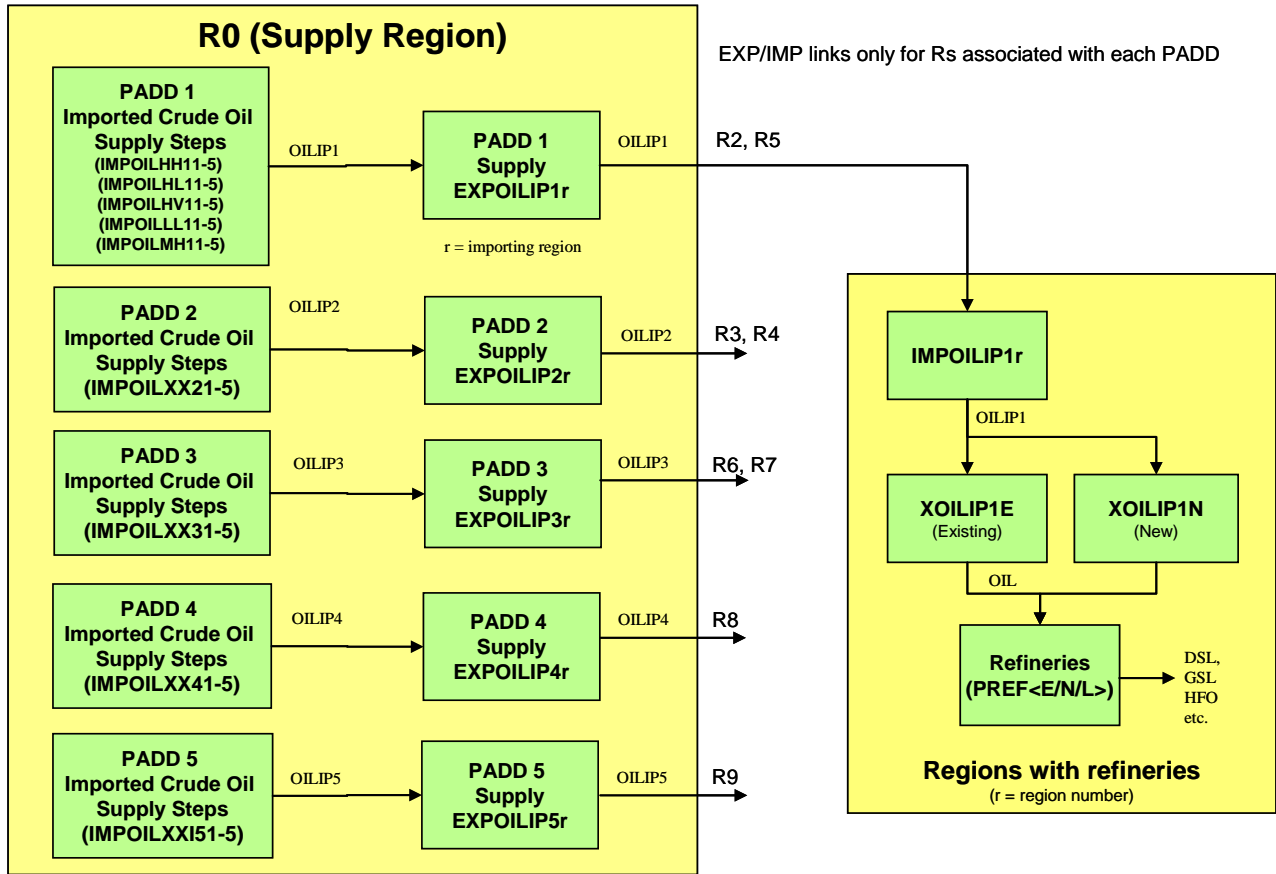


Figure 7: Imported Supply of High Sulfur, Heavy Gravity Crude Oil

Figure 8 illustrates the RES for domestic crude supplies. Domestic crude produced in R0 is shared to PADD regions using shares derived from the AEO 2006 forecast. These supplies are then available for import to the corresponding Census divisions. In addition, the oil trade data indicates pipeline transport between PADD regions, and this is modeled directly in R0 using specific X-processes (e.g. XOILDP13) with upper bounds based on the current pipeline capacity for these trades.

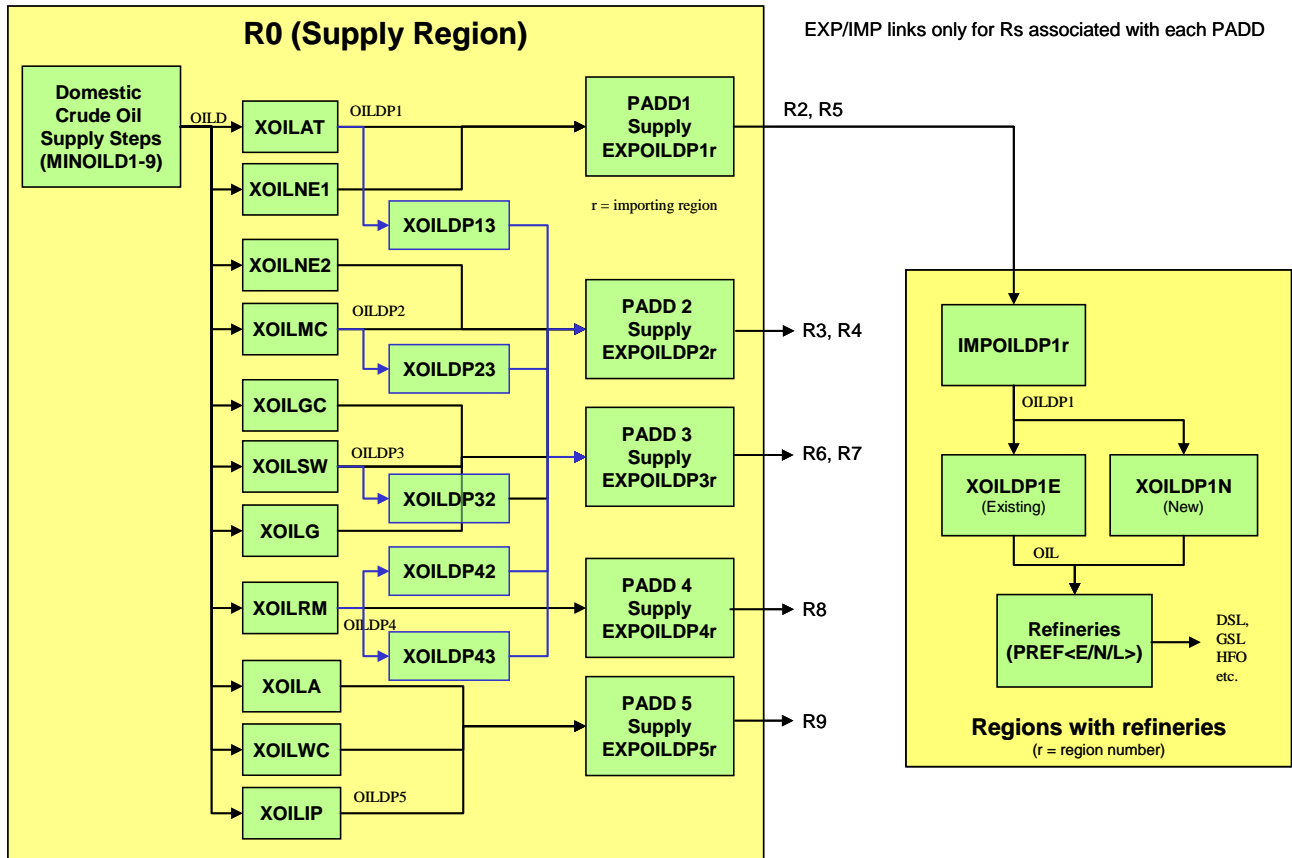


Figure 8: Domestic Crude Oil Resource Supplies and PADD Trades

2.2.3 Refined Petroleum Product Supply and Trade Structure

In US9r, the regional refineries produce petroleum products that will generally be used within the demand region, but each region can also import these same refined petroleum products from outside the country or from other demand regions and send the products to other regions as well, where transportation infrastructure exists.

Figure 9 depicts the RES for refined petroleum product supply and trade using diesel fuel in Regions 2 and 3 as an example. As with imported crude, NEMS-derived import supply step curves provide cost and quantities by PADD region. These are imported into R0, and are distinguished by the PADD region number in the energy carrier name. They are then available for import into the corresponding Census regions. This supply of imported products is assumed to take place via pipelines.

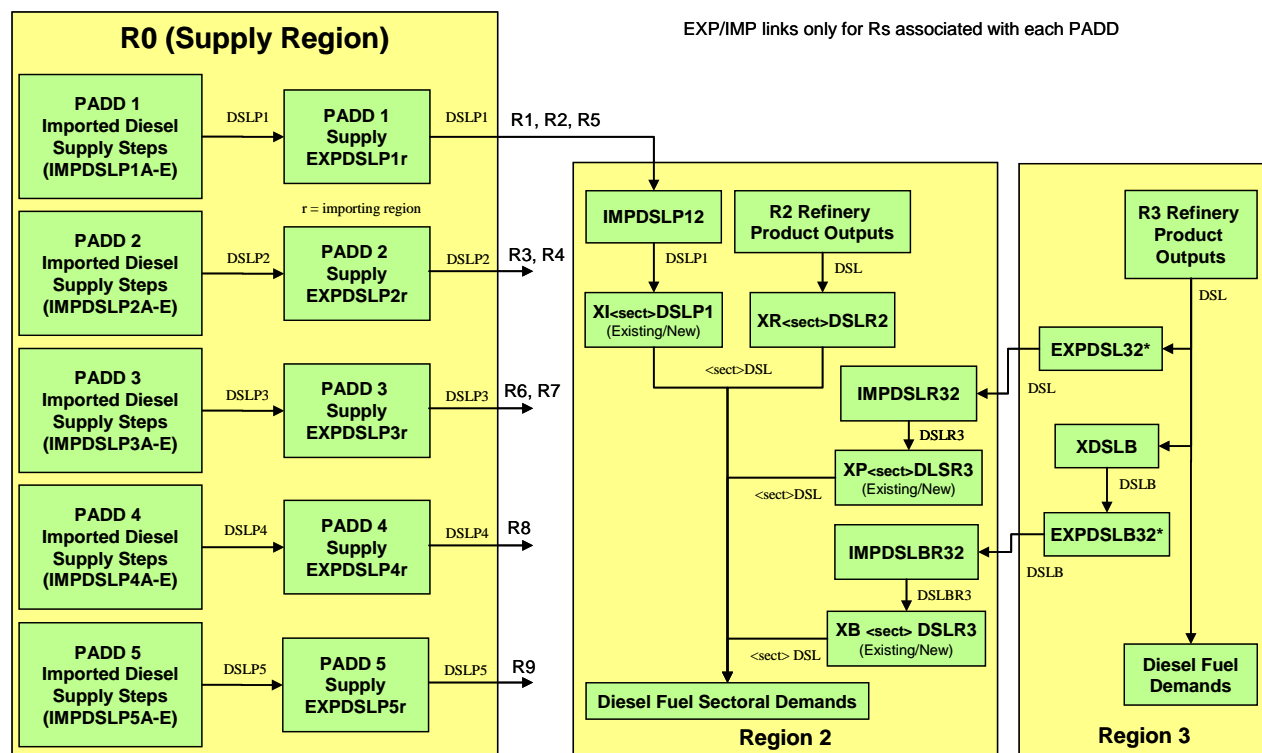


Figure 9: Refined Petroleum Product Supply, Import and Trade Processes

Refined oil products may also be produced by in-region refineries and traded between regions. Trade between regions can take place either by pipeline, river barges or ocean vessels. The pipeline trade links have existing capacity (annual throughput) limits and investment cost requirements for expansion. The barge/vessel trade links do not. The modeling of the upper bounds on the existing pipeline trade links was handled with a dummy material carrier just as with the Tier 1 coal transport limits to the electric sector. This process is illustrated in Figure 10 using the example of diesel fuel and showing both the PADD-region pipeline supply and the inter-region trades.

The refined petroleum product pipelines can carry a variety of refined products at different times, and to correctly account for its annual activity, it is necessary to sum the activity of all the possible refined oil products for each link. Therefore, the IMP processes for each imported or traded refined oil product supplies produce a dummy material carrier that is the same for all imported (or traded) products entering a demand region. This dummy material represents the total activity of that link, and it can be compared to the pipeline capacity (meaning annual throughput) for implementation of both the upper bound and the requirement for new investment when the existing capacity is exceeded. For the example in Figure 10, when the total amount of the dummy commodity (P1R2FLO), which is in the same units as the actual flow of the refined oil products, reaches the upper bound in the P1R2 Import Capacity process, additional flow through the real import process (IMPDSL12) can only take place if the additional flow of the dummy material goes through the P1R2 Expansion Investment process, where the required

investment cost is added. *Currently, the loadsheet does not have the investment costs for these pipeline expansions.*

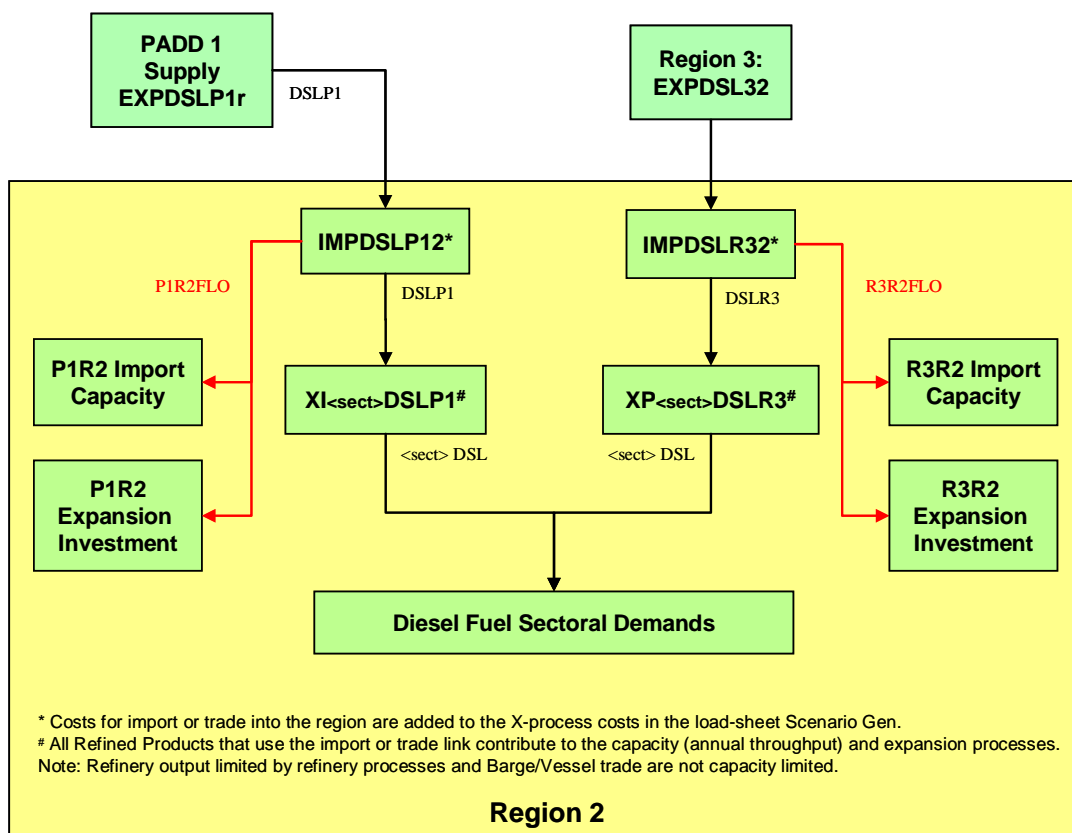


Figure 10: Pipeline Capacity (Annual Throughput) and Investment for Refined Petroleum Product Trade (Diesel)

2.2.4 Natural Gas Supply and Trade Structure ¹⁸

Figure 11 illustrates the RES structure for domestic natural gas supply. As with domestic crude, supply steps generated using the resource-driven approach are shared to PADD districts using AEO forecast values and are then available for import to the corresponding Census regions. The share processes in R0 are not fixed, but tied by adratios that allow flexibility in splitting the share amounts, which are specified by, to the specific PADDs. This approach was used because the Northeast OGSM supply region significantly overlaps both PADD1 and PADD2.

Natural gas is modeled as being delivered from the PADDs to each demand regions through pipeline processes, but currently these pipeline processes are not active because their cost is

¹⁸ For the SEE-REDP and China modeling activities natural gas is a focus. To accommodate the need for seasonal storage of gas an approach has been developed, using exiting ELC/LNK and a new seasonal storage constraint. Consideration will be given to whether such an approach is also advantageous for US9r. Also, it may be advantageous to “hide” the use ELC/LNK mechanism via ANSWER. If adopted for US9r such an enhancement could be considered for a Task 6 activity later in the project.

included in the supply curve costs according to the NEMS documentation. Within each demand region, natural gas is delivered to the five main end-use sectors using NEMS delivery markups, or it is traded to other regions.

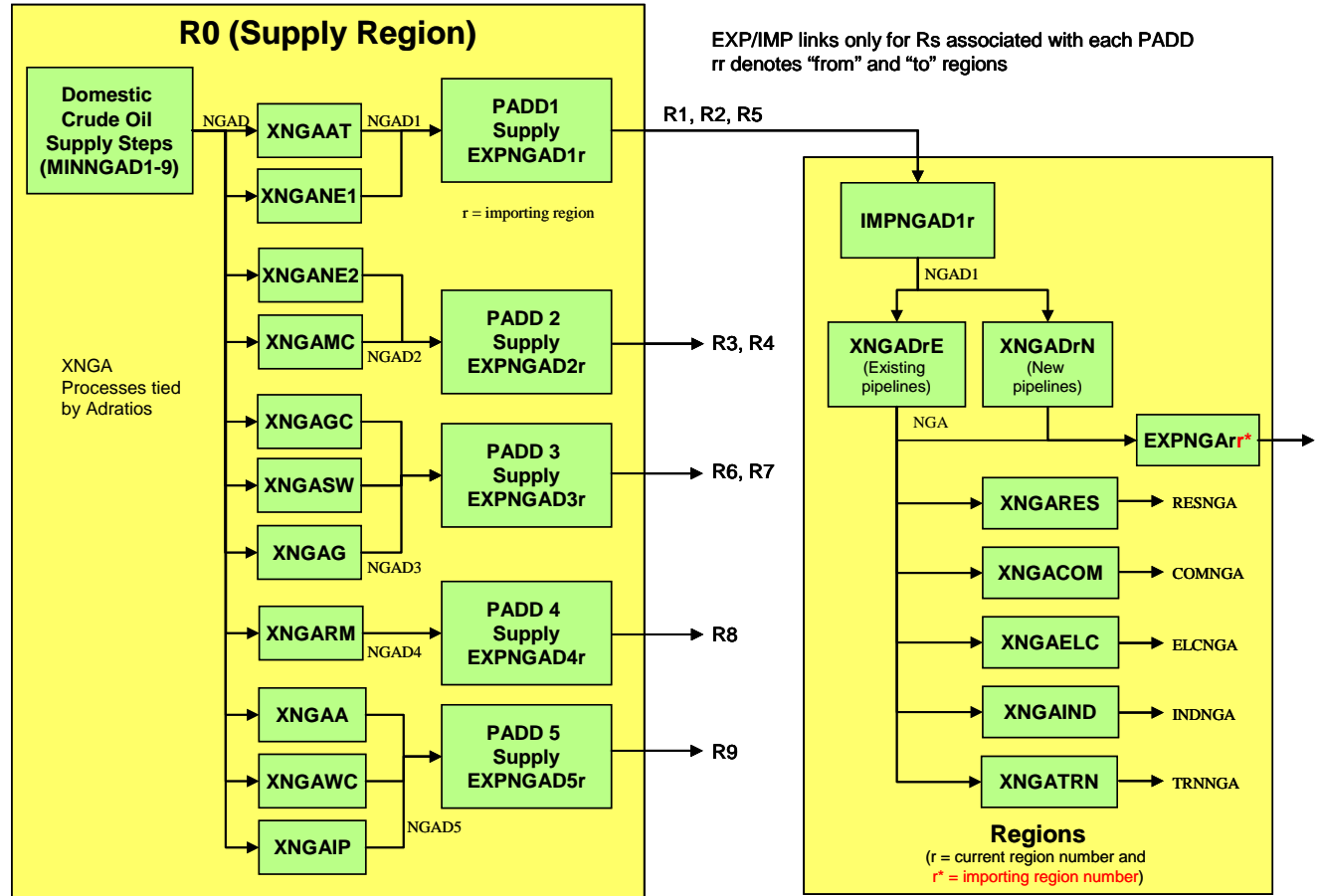


Figure 11: Domestic Natural Gas Resource Supplies

Figure 12 illustrates the parallel structure for imported natural gas supply and trade. Natural gas imports can come from Canada or through various LNG terminals. The existing capacity limits and the investment costs from expansion capacity are included through the traditional parallel Xprocesses, as shown in the figure. Data for both capacity limits and expansion costs were developed from NEMS data. Natural gas from these various processes is collected in the region and then distributed to the five main demand sectors.

Note that natural gas is exported to Mexico from regions 7, 8 and 9. Based on NEMS documentation, these flows are highly political, and are not expected to grow significantly in the future. Therefore, the existing/new pipeline capacity processes were not used to model this energy flow.

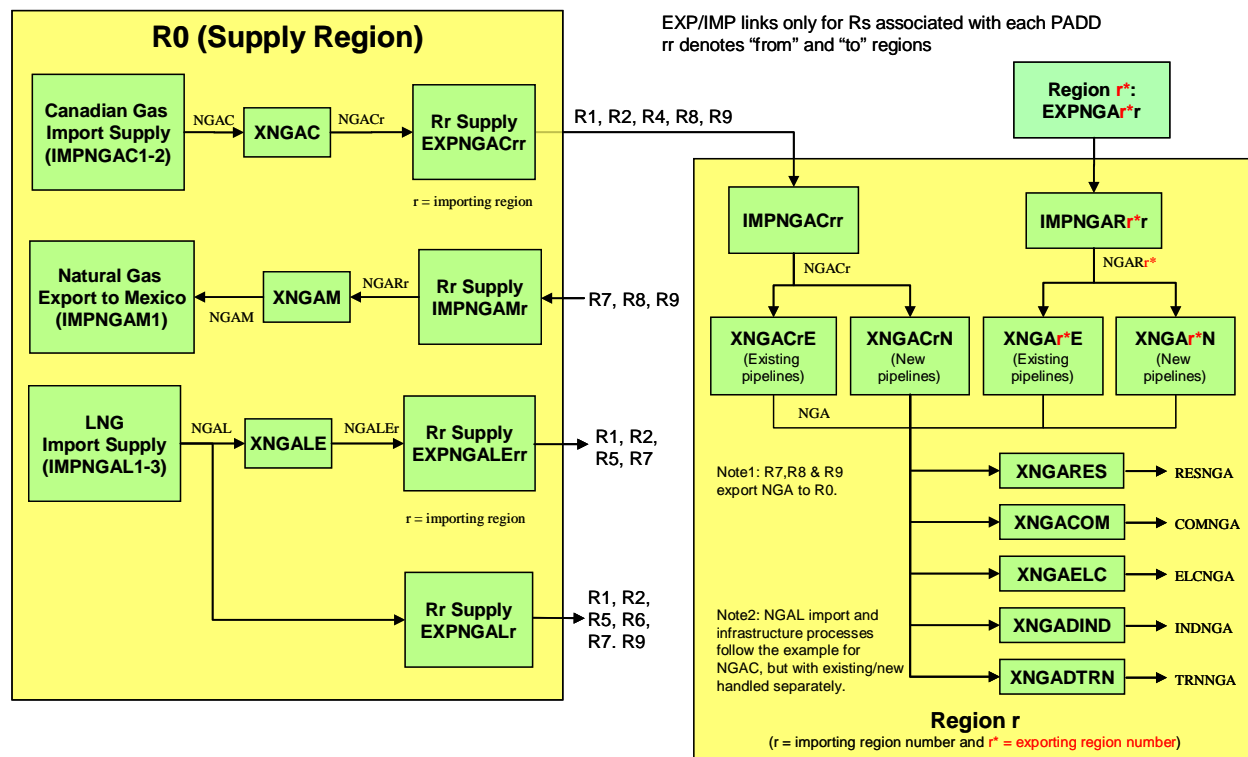


Figure 12: Imported/Exported Natural Gas Resource Supplies

2.2.5 Areas for Possible Modification and Improvement

More than any other segment of US9r, the petroleum and natural gas supply sector has involved the development of new methodologies and substantial new structures. These will require careful testing as the model is integrated and monitoring as sensitivity and scenario analyses are performed. Areas for particular attention include:

- The resource and DECAY-based approach to domestic oil and gas production and out year international production. All of the parameters on the Scenario Gen sheet should be experimented with through sensitivity analysis in order to determine appropriate ranges of values.
- The extensive transportation and trade structures. These are large, complex model structures which should be tested to insure their operating as expected as the model is integrated.

In addition, while we believe we have created the best possible transportation structure out of the available NEMS data within the current project scope, there are some areas of the NEMS data where understanding of how to best use it could be improved. Further research is needed in regard to the investment costs for expansion of refined oil product pipelines. In addition, further research is needed to understand why some of the costs for delivery of refined oil products from refineries to end user sub-sectors are negative. These costs are the difference between the refinery gate prices in each PADD and the end-use prices in each demand region. It is thought

that some of these negative numbers reflect special contract pricing data collected by NEMS that reflect historical end-use pricing, but this needs to be investigated more.

2.2.6 Updating the Workbook

The various AEO and NEMS input tables that are incorporated into the workbook can be readily updated as future editions of the AEO are published.

2.3 Ethanol and Biodiesel Supply and Transportation

Characterizations for ethanol and biodiesel supply are derived from the NEMS Petroleum Market Module (PMM). The PMM models two kinds of ethanol: corn-based and cellulosic, and two kinds of biodiesel: derived from virgin soybean oil and derived from yellow grease. Ethanol supplies are modeled as process technologies. Because the NEMS corn-based ethanol model includes corn prices in operating costs, corn is modeled here as a renewable energy carrier with zero cost. The cellulosic ethanol technologies obtain their inputs from the biomass supply sector. Because the NEMS biodiesel technologies are simple supply functions with no inputs, they are modeled here as resource extraction technologies.

This sector also includes transportation and trade technologies for ethanol, also derived from the PMM. Biodiesel is assumed to be traded like diesel.

2.3.1 Workbook Organization, Data Sources and Transformations

This “Smart¹⁹” workbook contains 9 worksheets as follows:

- **ANSv5_Home** – This sheet defines the Answer template region handling and version information.
- **Conv** – A list of conversion factors for use in the various data sheets.
- **Data-corn eth** – This sheet contains data from NEMS used to characterize corn ethanol technologies, including capital and operating costs (which include the price of corn inputs), existing capital stock, production bounds, federal and state subsidies, and energy inputs needed.
- **Data-biodsl** – This sheet contains data from NEMS used to characterize cellulosic ethanol technologies, including capital and operating, production and investment bounds, federal subsidies and technology start year.
- **Data-cell eth** – This sheet contains supply step functions in federal subsidies data from NEMS used to characterize biodiesel supply.
- **Data-eth trans** – This sheet contains data from the PMM documentation to characterize ethanol transportation costs.
- **Commodities** – Declaration sheet listing all energy carriers used in the template.
- **Technologies** – Declaration sheet listing all technologies carriers used in the template.

¹⁹ Underlined worksheets correspond to actual load sheets handled by ANSWER by means of CheckSheet and Import from Excel.

- **Tech Data** – Model input data. Values from the NEMS data sheets have been converted to MARKAL units. Dummy processes and transportation and bilateral trade links are specified.

2.3.2 Ethanol Supply and Trade Structure

Figure 13 shows the RES structure for ethanol supply and transportation trade for two representative regions. Corn-based and cellulosic ethanol are tracked separately, but then combined for consumption in the transportation sector. Because most of the ethanol production occurs in regions 3 and 4, NEMS allows transportation of ethanol from these regions to the other census divisions to supplement local production. In most regions, there are two different transportation cost steps, corresponding to different modes of transportation.

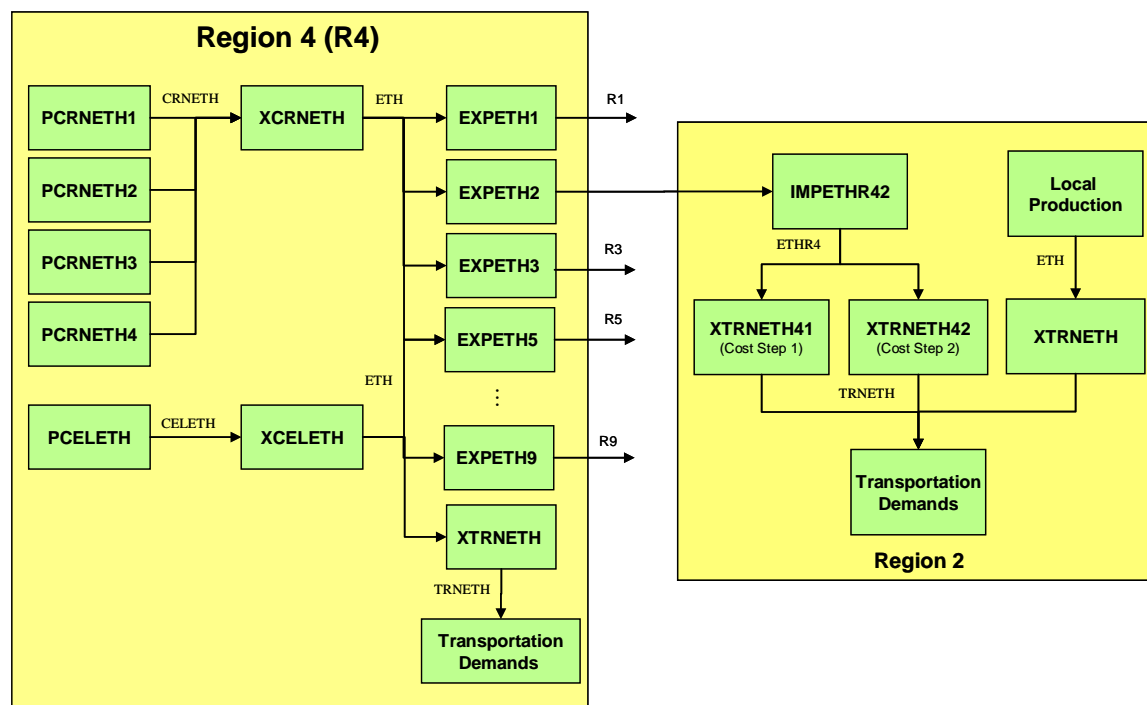


Figure 13: Ethanol Supply and Trade Structure

2.3.3 Areas for Possible Modification and Improvement

EPA may wish to compare NEMS assumptions about available quantities, costs, and ethanol transportation costs and limits against other sources when analyzing scenarios that may include large amounts of ethanol and/or biodiesel.

A blending process for E85 has been added, but costs and RESID have not provided for them as minor compared with overall cost of delivering E85.

2.3.4 Updating the Workbook

The relatively small amount of data in the workbook should allow for easy updating. Some has been derived from NEMS input files, which must be pasted in, and may be likely to change structure in future AEOs, and some is derived from Sections I and J of the PMM documentation, so both sources should be consulted for updates.

2.4 Renewable Energy Supplies and Technologies

2.4.1 Workbook Organization, Data Sources and Transformations

The Refineries “Smart²⁰” workbook currently contains 12 worksheets as follows:

- **ANSv5_Home** – This sheet defines the Answer template region handling and version
- **Commodities** – Input and output energy carriers for all renewable energy technologies, which currently includes three biomass types, solar and wind.
- **Technologies** – Technologies for biomass supply and solar and wind conversion, including four supply step technologies for each biomass type, four solar conversion technologies and three wind conversion technologies.
- **TechData Biomass** – Model input data (costs, and resource bounds) for all biomass supply steps in each demand region.
- **TechData Solar&Wind** – Technology characteristics (investment cost, O&M cost, capacity factor, and other data) for solar and wind conversion technologies in each region.
- **Solar data** – Source data for solar technology characteristics.
- **Wind data** – Source data for wind technology characteristics.
- **Biomass data** – Source data from ORNL on six types of biomass resources by state.
- **Adjustments** – Worksheet to adjust resource data to account for competing uses and heat content.
- **Resource Calculations** – Worksheet to compile state data into demand regions and consolidate six biomass types into three.
- **Supply Steps** – Worksheet to calculate resource supply steps for copying into TechData sheet.
- **Conv** – A list of conversion factors for use in the various data sheets.

2.4.1.1 Biomass

The methodology and data sources for the biomass resource supply curves are summarized below.

- The biomass resource data was developed by ORNL²¹ and provides estimated annual cumulative biomass resources available by state and price for urban wood wastes, mill wastes, forest residues, agricultural residues, switchgrass and short rotation woody crops (SRWC). This is also the biomass source data used by NEMS.

²⁰ Underlined worksheets correspond to actual load sheets handled by ANSWER by means of CheckSheet and Import from Excel.

²¹ Biomass Feedstock Availability in the United States: 1999 State Level Analysis, Marie E. Walsh, Robert L. Perlack, Anthony Turhollow, Daniel de la Torre Ugarte, Denny A. Becker, Robin L. Grahama, Stephen E. Slinsky, and Daryll E. Ray (updated January 2000.)

- The total available resource in each type is adjusted to account for existing uses and the data, which is in dry tons per year at four price steps (\$20/dt, \$30/dt, \$40/dt and \$50/dt) is converted to PJ based on the heat content of each type.
- The urban wood wastes, mill wastes and forest residues are combined into wood waste biomass resources, and the switchgrass and SRWC resources are combined into energy crop biomass to result in three biomass types for model purposes.
- Four-step supply curves are generated based on the available amounts of each biomass type at each of the four supply prices in 2000\$/PJ.
- Not every demand region has all three biomass types available (e.g., no agricultural waste biomass in New England). However, the full matrix of supply curves has been retained in the spreadsheet. This approach provides EPA flexibility to do scenarios on more robust biomass resource estimates if it is desired. There is room to argue that the ORNL data is conservative for energy crops in that their estimation model is based on analysis of arable land, and does not consider marginal lands or dual purpose lands (e.g. highway medians).

2.4.1.2 Solar

Solar energy is not characterized as a resource because it is abundant and ubiquitous. However, there are important limitations in its conversion to electricity or heat that are typically captured in technology characterizations. The methodology and data sources for the solar energy conversion technologies are summarized below.

- Two broad technology types are modeled: solar photovoltaic (PV) and solar thermal concentrating (ST). Three types of solar PV technology are modeled: central electricity generation plants, distributed generation for residential application and distributed generation for commercial application. One central solar thermal concentrating technology was modeled.
- The capital and O&M costs²² for each technology type were taken from NEMS input data to 2035 and extrapolated to 2050.
- The other key parameter characterizing solar technologies is the capacity factor (CF) in each model time slice. NEMS uses nine time slices that do not correspond to the typical time slices used in MARKAL. Therefore, for the PV technologies, the RETScreen²³ PV3 model was used to generate annual capacity factors for typical PV installations in each demand region using the region's characteristic city as indicated in the NEMS model input data.
- Seasons were defined as S=June, July, August; W=December, January, February; and I=March, April, May, September, October, November. The annual CFs for these seasons were converted to time slice capacity factors using the actual daylight (and nighttime) hours for each season in each region's characteristic city.
- The limitation of this approach is that it lacks flexibility. For the NEM model, NREL developed a PV calculator that allowed PV technology CFs to be generated for

²² Assumptions to the Annual Energy Outlook 2006, Energy Information Administration, Table 74, page 134.

²³ <http://www.etscreen.net/ang/home.php>

characteristic cities in New England for any variety of annual time slices. Such a tool is needed to provide US9r with similar capability, but it is beyond the scope of this contract.

- Solar thermal concentrating technology operates on reflected sunlight and uses only the direct rays of the sun, unlike PV systems, which absorb sunlight whether it is direct or scattered in the atmosphere. Therefore, this technology type only operates in regions R4, R7, R8 and R9, where sufficient annual amounts of direct sunlight exist.
- Solar thermal concentrating technology has the ability to integrate thermal energy storage into the plant design and achieve higher capacity factors than are possible with PV systems. Therefore, the CFs for this technology were calculated starting at 0.3, which is typical of the new systems being built in the southwest, and progressing to 0.6 based on increasing amounts of thermal storage being incorporated into the plant designs. The capital costs reflect this increased amount of thermal storage.
- Another component of properly characterizing solar energy is growth rates on the technologies and upper bounds on their total implementation. For PV technology, these limits can be calculated, for example by determining the total available roof space for commercial installations. However, in practice these limits are quite large and do not generally inhibit implementation of the technology except in very high penetration scenarios.

2.4.1.3 Wind

Wind energy, like solar, is not characterized as a resource but as a set of technology options. The methodology and data sources for the wind energy conversion technologies are summarized below.

- The NEMS input data provides capital costs²² and capacity factors for three wind technology types based on the class of wind resource (Class 4, Class 5 and Class 6) out to 2035. The capacity factor values were extrapolated to 2050 using the NEMS value for ultimate wind CF in each wind class.
- The NEMS input data also provides fractional energy outputs for 15 electricity supply regions according to nine time slices. This fractional energy data was converted to six time slices that are approximately equivalent to the time slices used for the solar energy technologies, and the CFs for each technology, region and time slice were calculated from the technology CF times the regional time slice energy fractions.
- The upper bounds for each wind class technology are needed to properly characterize the wind potential. These upper bounds are calculated from GIS analysis of the wind resource maps for the US. The calculation typically incorporates exclusions of protected and sensitive area, such as urban areas, national parks, wildlife preserves and other scenic areas. The bounds are calculate for each class and can also determine the bounds according to distance from transmission interconnection. These bounds are needed to properly constrain the wind technology implementation. However, their development is outside the scope of this contract.
- The NEMS input data also provides cost data for transmission interconnection for three distances to the grid (5 km, 10 km and 20 km) I each electricity supply region. To use this data, additional wind technologies types must be added that incorporate these added costs and have upper bounds that correspond to the size of the resource (available area)

within the specific distance and wind class. These added wind types have not been defined because the necessary wind upper bound data is not available.

2.4.1.4 Geothermal

Following discussions with EPA, it was agreed that geothermal resources would not be characterized at this time in US9r, but that information on how NEMS models geothermal resources would be provided. NEMS represents geothermal resources by 51 known sites in the Southwest, Pacific Northwest, California, Alaska and Hawaii. Each site is characterized by 4 levels of electric output potential (MW), capital costs for 4 components (exploration, drilling, pipeline and other field, and power plant), a capacity factor, fixed O&M cost, heat rate, and carbon dioxide (CO₂) emissions rate. The first level of potential capacity is assumed to have the base capital costs, while the next 3 levels have increased costs due higher drilling, field, and/or exploration costs. The geothermal capital costs are also affected by learning-by-doing in a similar fashion as all other generating technologies.

A limit is imposed on the number of megawatts able to be built at any site in a specific year (annual build bounds) in order to better represent industry practice of gradual expansion at geothermal sites; bounds may be modified by individual site by year. For the reference case AEO2006, each site was permitted a maximum development of 25 megawatts per year through 2015 and 50 megawatts per year thereafter.

2.5 Nuclear Fuel Supplies

Following discussion with EPA, EPA has decided to retain the nuclear fuel cycle model in EPA-NM. Supplies and fuel cycle technologies will be located in R0, given the national nature of nuclear fuel supplies and the relative unimportance of transportation costs in nuclear fuel costs. The file nems2006nuclearfuelcost.xls, which shows annual nuclear fuel costs from AEO 2006 and a suggested extrapolation to 2050, has been provided to aid in calibration.

3. Conversion and Process Technologies

3.1 Electricity sector -- general considerations

This section discusses the electricity sector for the US9r model. Because the EPA modeling team has responsibility for modeling the sector, this section is limited to a discussion of issues that should be considered in modeling the sector and, where appropriate, recommended approaches and possible data sources. Issues considered include data sources and level of aggregation, time-slices and load shape, plant retirement and life extension, and emissions. The approach to electricity trade is discussed in Section 3.2.

3.1.1 Electric Generation Data Sources and Aggregation

The recommended data sources for existing generation technologies are EIA Forms 860 (existing and planned units), 767, 759/906 and Form 1 which collectively list generating unit capacity, prime mover, fuel sources, location, plant operation and equipment design (including environmental controls), fuel consumption and quality and for the larger investor-owned plants the non-fuel operating costs. Each survey form has its own universe of units covered. All units are covered by one or more of the forms. These sources will be used for the NE12 model, so their use for US9r would improve consistency between the models.

Because these forms list every plant regardless of size, plants must be aggregated to an appropriate level to obtain a manageable number of technologies that still adequately represents the diversity of existing plants and their differential use in the system. In the NE12 model, where regions are individual states, all existing generation units above a specified capacity level will be represented as individual technologies, retaining all unit-specific information. Plants below the capacity threshold will be aggregated by fuel type and other factors.

For the US9r model, different levels of detail and structure of aggregation may be appropriate. Retaining individual units will greatly increase the number of technologies. However, because the data sources include location information for these units, retaining them could be used to aid in geographically mapping emissions.

Factors and issues to consider in choosing aggregation level and structure include those listed here²⁴.

- Location
- Prime Mover
- Fuel(s)
- Heatrate (for units consuming fossil fuels)
- Utilization Rates (renewable units in particular)
- Non-Fuel Operation and Maintenance Costs (Fixed, Variable and Capital Additions)
- Emission Controls (FGDs, SCRs, SNCRs, Combustion Controls, Particulate Controls)
- Cost and Performance Parameters for Potential Emission Control Retrofits
- Size

²⁴ The IRG team is developing for the NE12 model a mining utility to extract this data, aggregate it to the appropriate level and group, and prepare it for MARKAL. This tool could be adapted and extended for the US9r model in order to simplify data preparation.

- Age
- Must-run Status

3.1.2 Plant Lifetimes and Retirement

The EPA national model, along with many energy models, assumes a technical lifetime of 30 to 40 years for most power plants. However, due to the structure of the electric power sector and particularly emissions regulations, it has been economic to extend the lifetimes of many plants far beyond this initial assumed lifetime. The EIA Form 860 data includes many plants that are already more than 30-40 (even 50-60) years old, which are not expected to retire anytime soon. Some mechanism for handling life extension for these plants is necessary if system costs and emissions are to be modeled adequately.

In NEMS, two types of life extension options are modeled. First, nuclear power plants are given the opportunity to pay a onetime license extension cost when they reach the end of their initial 40-year license horizon. Paying this cost obtains an additional 20 years of life. The cost to achieve the extension is dependent on whether or not the unit has previously replaced its nuclear steam supply system. The cost is considerably higher if this component replacement has not happened previously.

For existing coal plants increasing "recapitalization" costs is incurred -- an annual capital addition charge which is stepped up after 30 years of operation -- essentially an increase in fixed O&M -- in each model year as they age. In both cases, the model trades off the economics of paying these going forward costs to extend life vs. retiring these plants and building new ones to meet capacity needs.

MARKAL contains no explicit mechanism for modeling an economic decision to retire a plant. Technologies remain in place until the end of their LIFE, paying fixed operating and maintenance costs regardless of operation, and, in the case of electricity generation technologies, contributing their capacity to the peak reserve requirement. MARKAL also contains no obvious mechanism for a retrofit option. However for both an approach can be designed by introducing a new technology in the model year when the retrofit decision must be made, and tying the upper limit of capacity to the old technology through an ADRATIO or IBOND. Then the new cost and performance characteristics take over, and the old plant's values are 0ed out²⁵.

3.1.3 Emissions

The EPA national model tracks emissions of CO₂, SO_x, NO_x, VOCs, and PM₁₀ from the power generation sector. Emissions are accounted for using process technologies on the fuel input streams. The coal supply and trade structure proposed in Section 2, which retains distinctions between coal ranks and sulfur levels, will feed in appropriately to the current structure.

If a decision is made to model mercury emissions, both the coal and emissions accounting structures will need to be adjusted accordingly. The EIA coal data used to develop the coal supply curves does contain mercury levels by source region and coal type, and mercury content

²⁵ When EPA's approach to modeling the power sector is defined, and passed along, this mechanism can be elaborated upon at that time.

for each of the aggregated coal types has been provided in the coal sector template as a starting point for doing so.

3.1.4 Time-slices, Load Shape and Electricity Trade Timing

In Section 4 of this report we address the new flexibility in defining electricity load slices that has been developed for the EPA US9r modeling framework. Before discussing some of the factors driving the selection of the number of slices and the definition of what goes into each slice, as MARKAL does not know about time zones, it is important to point out that the discussion below regarding electricity trade should be viewed as occurring *at the time-slice level*. In order to incorporate electricity trading into modeling design we must address the fact that electricity is produced and consumed simultaneously. That is to say, at any given moment, the electricity being taken off the grid by consumers (demand) is exactly equal to the amount of electricity being injected into the grid (supply) at that same moment.

In order to setup electricity trading across regions, the demand levels must be adjusted to account for the time zone differences potentially existing between the exporting region and the importing region. This need to synchronize time is done by making sure the hours represented by any given load slice in each of the census regions represent demand that is occurring at the same time. For example, if we are addressing electricity trading that is occurring say at noon on the east coast, then the load levels occurring at 11:00 AM in the Central time zone, 10:00 in the Mountain time zone, etc., are the loads that could be served by the potential export from generating facilities in the Eastern time zone, and vice versa. When we adjust the time-slice data throughout the model in this fashion, we describe this as setting the “prevailing time zone”. For purposes of the EPA US9r modeling, we will establish the load slices according to a prevailing Eastern Time Zone convention.

The factors that drive the selection of the number of load slices can be reduced to a concern expressed as follows: How many slices do you need to adequately identify the economic differences in operating modes of generating facilities including the need to account for seasonal maintenance downtimes? Operating modes in this context have a few dimensions including: 1) establishing the economic level of operation of high fixed cost but low variable cost facilities versus low fixed cost but high variable cost generating facilities; 2) the potential limitation in output associated with technologies that operate only during the daylight hours (e.g., solar); and 3) the opportunity to account for injection during off-peak hours and withdrawal from storage technologies during peak hours. In addition, there is a need to capture the limited duration very high load levels associated with the peak load in the region (and the associated reserve requirement to account for unplanned or forced outages and extreme variations in weather).

Given the need to address the opportunity for trading between regions and the need for a sufficient number of intermediate load levels to capture the role of older plants being pushed up in merit order (i.e., playing a cycling or intermediate mode of operation) by new baseload technologies, a number of load slices between 9 and 15 would seem sufficient. Note that the NEMS model uses 11 load slices in its capacity-planning model (ECP) to address the concerns expressed above²⁶.

²⁶ Consideration should be given to the expectation that the sum of the end use load fractions will lead to an overall load shape that is more peaked than the system level load would actually experience. It may be worthwhile to investigate the introduction into the MARKAL framework of an approach that deals with

Figure 14 provides an illustration of the NEMS ECP load slices²⁷. [A similar approach to load slices is being investigated for application in the NE12 model.]

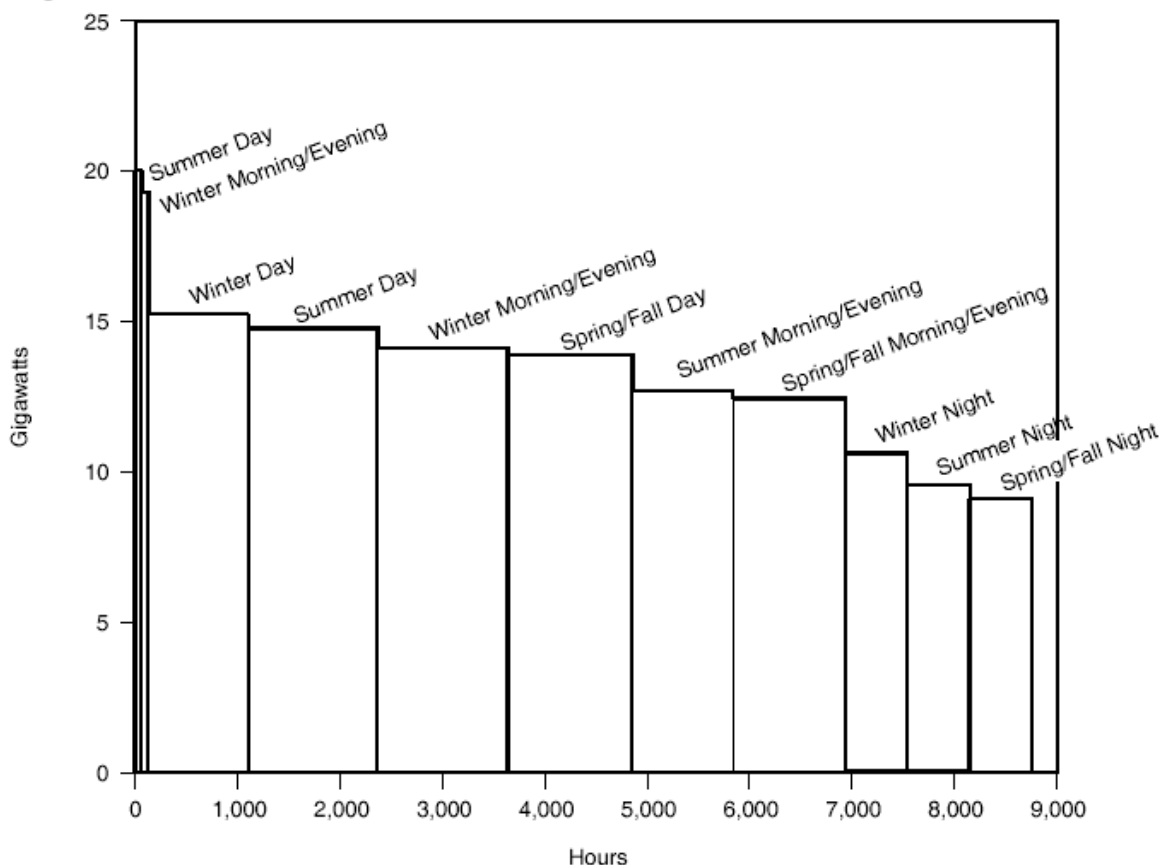


Figure 14: Load Duration Curve with Time-of-Day and Seasonal Load Segmentation

3.2 Electricity Trade

Electricity trade limits for modeling in NEMS, IPM, POEMS and other models have been derived from the NERC reliability seasonal assessments. The limits provided were originally derived by NERC28. They represent the non-simultaneous transfer capability of the transmission network to transfer electricity from one area to another for a single demand and generation pattern. Different patterns of demand and generation will cause variations in transfer capabilities that could vary on a seasonal, day-to-day or hour-to-hour basis.

the “deltas” instead of the total load levels as is done in NEMS or is there some other way to address this concern?

²⁷ Source: Page 71, The Electricity Market Module of the National Energy Modeling System Model Documentation Report, March 2004, Energy Information Administration.

²⁸ Assembled by ICF Consulting for use in the IPM modeling framework.

The interface between two areas is typically made up of a number of transmission lines of varying load carrying capability. Further, the existence and location of the existing generating facilities and major transformers that are used to serve sections of the grid have an additional limiting impact on the transfer limits between two regions. In order to determine the impact of the addition of a new transmission line (or for that matter generating unit), the regional transmission entities (Reliability Councils and/or Independent System Operators) typically perform a number of simulations using power flow models to simulate the anticipated varying patterns of demand and generation that might occur. These power flow models involve complex engineering calculations of the impact of the addition of new facilities and the potential implications in the event of the loss of a major transformer, transmission line or generating unit on the system.

Finally, as the US9r model simulates the growth in the energy market on a regional basis, it will be assuming the placement of the new generating facilities within each region along with the interconnection of these facilities to the existing transmission grid. It is only appropriate to assume that these facilities will be integrated into the grid with an eye towards increasing regional reliability. These facilities could in fact by themselves contribute to increasing the transfer capability between two neighboring regions.

Given the complexity of the power flow problem, a significantly simplified approach to electricity trade in the US9r is provided. This approach assumes the transfer limits as published by NERC and captured in the IPM modeling framework could be further simplified to capture the potential flows between Census divisions.

Trade in electricity is broken into domestic inter-regional trade, where currently existing, and international transfers between the Canada and Mexico and the US. The Canadian transfers are identified by Province. For the international transfers there is a simple series of three supply steps available to identify a price for the imported electricity. Since the IPM modeling framework did not address international electricity trade (other than by exogenous assumption), these values were extracted from the NEMS transfer limits data files. Again, the original source for this data is the NERC seasonal reliability assessments.

3.2.1 Workbook Organization, Data Sources and Transformations

Because the transmission losses associated with interregional transfer will be already accounted for in the TE(ENT) parameter, the economic "friction" associated with interregional trade will be represented using an imposed dollar cost. This process is similar to that used by DOE and FERC in their analyses of the FERC Standard Market Design²⁹.

This "Smart"³⁰ workbook contains 10 worksheets as follows:

- **ANSv5_Home** – This sheet defines the Answer template region handling and version information.

²⁹ Report to Congress: Impacts of the Federal Energy Regulatory Commission's Proposal for Standard Market Design, U.S. Department of Energy, April 30, 2003 and Economic Assessment of RTO Policy; Prepared for: Federal Energy Regulatory Commission, Prepared by: ICF Consulting, February 26, 2002.

³⁰ Underlined worksheets correspond to actual load sheets handled by ANSWER by means of CheckSheet and Import from Excel.

- **Commodities** –Declaration sheet listing all domestic transfers (ELCR#) and for each international source (e.g., Mexico and the appropriate Canadian Provinces, as listed in Figure 14).
- **Technologies** –Declaration sheet listing all import, export and grid technologies required for depicting the electricity exchanges. This includes exports from R0 for the international exchanges, and export/import pairs for R1 through 9, with the associated grid limit/expansion processes from each export region as found in each import region. Note the Col-A uses a formula based upon the existence or not of an entry in the Winter Limit (top) table on the Domestic sheet to determine the region # stated, or the “* Not Allowed” comment removing said option. This key column is then used on the two DomELC_Trd/XLim sheets to control whether an exchange is permitted or not. For the international exchanges, since the number of routes is limited, the entries have been made manually by checking the permitted transfers based upon the Winter (top left) table on the International sheet.
- **CommData** – Is currently empty, but has been left in case it is decided to put the transmission efficiency loss directly on the ELCxx source, though more likely this loss will be put on the Xlnk grid processes. If the Xlnk process are used then this sheet may be removed.
- **DomELC Trd** – Lists all domestic possibilities for electricity exchanges with those not currently available commented out (as “* Not Allowed”) based upon Col-A of the Technology sheet. By export region, for each viable export there is an indication of to which other region electricity from it flows by means of a 1 in the BI_TRD(ELC) column for the importing region. The convention employed for the domestic bi-lateral trade is that in the export the electricity is name ELC (competing with the rest of the electricity demands in the region) and comes into the importing region with the export region name appended to ELC (e.g., ELCR2 would be export from R2 into some other region). This convention is signaled by the <EXPREG> Qualifier for the BI_TRD(ELC) parameters.
- **DomELC Lim** – Lists all domestic possibilities for electricity exchanges with those not currently available commented out (as “* Not Allowed”) based upon Col-A of the Technology sheet. For each possible exchange there is a pair of Xlnk process (where lnk reflects the linked ELCr#, and existing (E) and new (N)) indicating the current maximum transfer capacity (RESID) and the seasonal maximum as imposed by the availability factor (AF(td)). [Note that when load the “Set IBOND=0” option should be specified in ANSWER so that the existing grids (those with a RESID value) can not be expanded.]
- **IntELC Trd** – Lists all the international possibilities for electricity trade as originating in R0. The permitted regions into which electricity flows from each source (e.g., Mexico and several Canadian Provinces) are indicated means of a 1 in the BI_TRD(ELC) column for the importing region. The convention employed for the international bi-lateral trade is the electricity is named ELCxx (where xx is a 2-char designator of the source) in both the exporting (R0) and importing regions. This convention is signed by the <Same> Qualifier for the BI_TRD(ELC) parameters.
- **IntELC Lim** – Lists all international possibilities for electricity trade. For each possible exchange there is a pair of Xlnk process (where lnk reflects the linked ELCxx, and existing (E) and new (N)) indicating the current maximum transfer capacity (RESID) and the seasonal maximum as imposed by the availability factor (AF(td)). [Note that when

load the “Set IBOND=0” option should be specified in ANSWER so that the existing grids (those with a RESID value) can not be expanded.]

- **IntELC Trd-PB** – Lists all international supply and export options. For each possible option the technology sheet entry keys to the period 2000 value to determine whether the option is active. Currently placeholder data is provide pending discussions with EPA.
- **Domestic** – Is the main control sheet of depicting allowed bi-lateral electricity exchanges between two regions. The Winter table (up top) is the main control table referenced by the Technology sheet to control “* Not Allowed” when no entry existing in the matrix. The RESID is set to the maximum of the Winter/Summer levels, and the seasonal maximum availability then determined from said maximum. Adding or removing an entry in the matrix will result in reflecting of that information to the Technology sheet which then cascades to the other Domestic sheets as appropriate.
- **International** – Is the main specification sheet of depicting allowed electricity trade between external regions (Mexico and Canada) and the internal regions. Note that only imports are considered at this time. The Winter table (up top) is the main guide table referenced to decide what entries need to be included on the Technology and other sheets. The RESID is set to the maximum of the Winter/Summer levels, and the seasonal maximum availability then determined from said maximum. The user must manually make all necessary adjustment if adding or removing an entry in the matrix. At the bottom of the sheet are the electricity prices/limits for up to a 3-tier supply step curve. The availability or not of each step is controlled by whether a limit is provided for 2000 (in column O). At the moment the information provided is just a placeholder. For Exports from the US to outside there is one additional table at the very bottom of the worksheet.

The data flow of the various worksheets is depicted in Figure 15. As already noted the domestic path is fully determined and controlled by the entries on the Domestic sheet, but the use must make the necessary adjustments if an international option is removed or added.

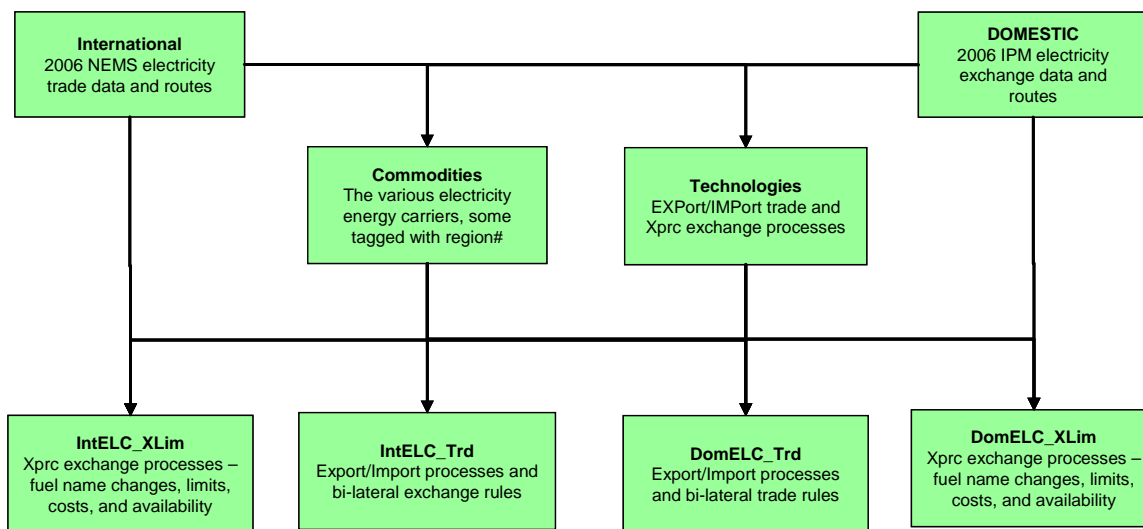


Figure 15: Electricity Trade Workbook Flow

3.2.2 Electricity Trade Structure

In US9r conversion technologies in each region will produce electricity for local consumption and possible export to other regions. Some regions will also be able to import electricity from Canada or Mexico via the R0 supply region, where transmission infrastructure exists.

In MARKAL bi-lateral electricity trade may either be done using the traditional annual IMP/ELC options, or time-sliced versions of same. It is recommended that the time-sliced approach (activated by means of the BI_TRD(ELC) parameter in the ANSWER loadsheets) be used so that each time-slice decision can be taken by the model independently.

Figure 16 depicts the general structure proposed for electricity supply and trade using Region 1 as an example. Electricity (ELC) can be produced internally, as well as imported from R0 (that is from some Canadian Provinces in this case) and from R2. These imports are structured similarly to the import of other energy carriers described in other sections.

An import option (IMPELCxx1) linked to the export option in R0 (EXPELCxx1) represents imports from Canadian Province xx in this example. Transmission infrastructure limitations or expansion requirements are represented by the infrastructure processes (XELCxx>E/N), where xx> is the 2-character designator for the exporting Province. Note that the XELCxxE/N processes need to be declared MARKAL grid (LNK) technologies to retain the time-slice detail.

Imports from another demand region are represented by trade to R1, which can take place from any other region connected by transmission infrastructure to region R1. As shown in Figure A.2, the trade link for ELC from R2 consists of the EXPELC21 option in R2 coupled to the IMPELCR21 option in R1. Note that the EXP tech name ends with the number of the import region, and that the imported electricity retains the region number of the export region in the <encR#> name (ELCR2) until it passes through the transmission infrastructure processes and is converted to ELC, which is the core name for consumed electricity.

The transmission infrastructure processes in R1 will define the costs and upper bounds of trade between the two demand regions using existing infrastructure (XELCR2E), and when the upper bound is exceeded, additional trade will have to flow through a new upstream process (XELCR2N) that will contain the investment costs and bounds for additional transmission infrastructure. Note the traded electricity may be subject to transfer “markups” on the Xlnk processes.

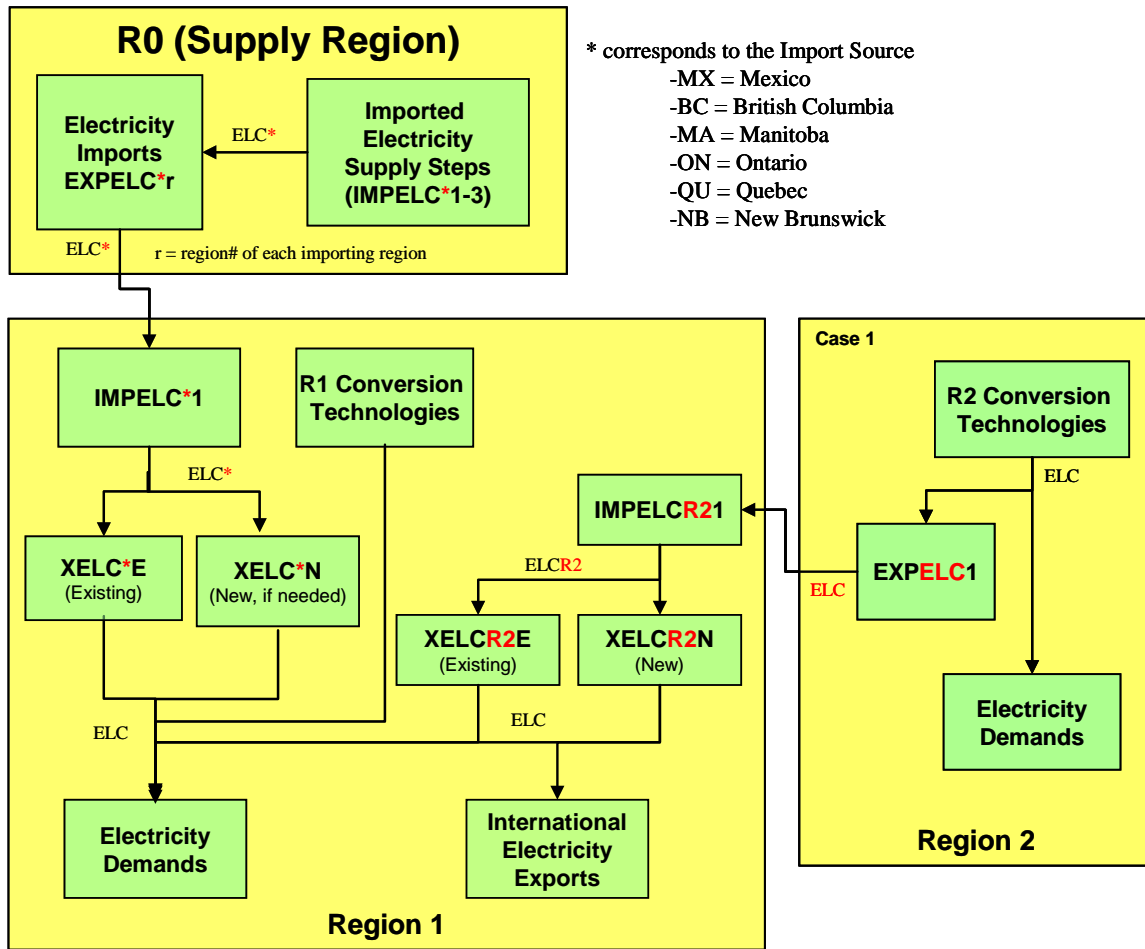


Figure 16: Electricity Trade RES Structure

3.2.3 Areas for Possible Modification and Improvement

If deemed necessary the international trade options could be “programmed” in a manner similar to the domestic so that updating of the International sheet would result in the proper propagation of the associated options throughout the workbook. However, as the number of existing links are and prospects for new links are limited it was felt that this could be handle manually if changes are required.

The transfer limits included in the model represent the potential flow between two regions not the expected level of flows. Actual flows indicated by the model will not likely correspond to any particular historical period. As such, a key modeling activity will be the review and potential application of analyst adjustments to these limits to assure the model behaves within acceptable ranges of values.

In other electricity modeling frameworks, an economic hurdle is inserted to establish the minimum threshold advantage required before trade can occur. This modeling mechanism provides a means to limit the amount of over-optimization that would occur absent these considerations. It also provides the modeler with a tool to limit the flows within a given range of acceptable outcomes based on analyst judgment. Care must be taken when applying these types of economic friction measures in that they represent barriers to trade but not actual “real costs”.

EPA may want to consider the implementation of such a modeling device to provide a greater amount of control over the inter-regional trading that will occur in the model. See prior discussion in Section 3.2.1 for additional discussion of how this is implemented in the modeling framework.

Using data extracted from the Reference Case of the 2006 AEO, a table of regional international imports and exports has been established. The model has been set up to accept the international exports as an additional demand to be satisfied on the part of the exporting region. The imports have been established in a similar fashion wherein the quantities can be imported at zero costs. By taking this approach, the marginal costs of satisfying these incremental flows will be captured in the modeling framework. [If EPA would like to establish the total costs including the costs of these flows, then the three step supply curve framework previously discussed can be implemented and the quantities provided act as upper bounds on the imports.]

There are three data tables on the International sheet for the imported electricity supply steps and the exported electricity price that will be completed after discussions with EPA. Also, the electricity transmission and distribution parameters associated with electricity have not yet been introduced pending discussions with EPA regarding the overall representation of the power sector.

3.2.4 Updating the Workbook

To introduce a new trade link between two domestic regions the appropriate entry just needs to be made in the Winter and Summer Transmission Flow Limit tables. Once entered (for Winter) the “* Not Allowed” on the Technology sheet is changed to the export region number and the link is thereby activated on all ancillary worksheets. The levels introduced are then propagated down to the seasonal AF tables, which in turn make their way to the DomELC_Lim sheets to set the RESIDs and AFs.

NERC has periodically released new assessments of the potential power flows between neighboring regions. It is recommended that a system to monitor and capture the revised data be established by EPA.

3.3 Utility Coupled Heat and Power

The approach to CHP began with a review of its treatment in the NEMS modeling framework. Table 14 below provides an overview of the components of CHP as contained in the EIA forecast.

From that review³¹, the following observations and recommendations are made:

- Residential and Commercial CHP are extremely small and relatively unchanged over the forecast period. The recommendation is to not model these in the EPA US9r.
- NEMS tracks a small amount of CHP from EOR. Again the values are very small and flat over the time horizon. The recommendation is to not model these in the EPA US9r.

³¹ Note: Appendix A “Non-Utility Electricity Capacity” provides a summary of the AEO Reference forecast for Combined Heat and Power capacity.

Table 14: Combined Heat and Power [GWe]

Sector	2003		2015		2030	
	GWe	%	GWe	%	GWe	%
Industrial	21.6	78%	26.3	74%	34.7	56%
Refining	4.3	15%	7.3	21%	25.5	41%
Enhanced Oil Recovery	0.9	3%	0.9	3%	1.0	2%
Residential and Commercial	<u>1.0</u>	<u>4%</u>	<u>1.0</u>	<u>3%</u>	<u>1.2</u>	<u>2%</u>
Total Traditional Cogenerators	27.8	41%	35.6	47%	62.3	61%
Total Non-Traditional Cogenerators	<u>40.4</u>	<u>59%</u>	<u>40.5</u>	<u>53%</u>	<u>40.5</u>	<u>39%</u>
Total Combined Heat and Power	68.1	100%	76.1	100%	102.9	100%
Prepared By OnLocation, Inc.						
Source: Supplemental Tables Generated From Reference Case, AEO 2006						

- Industrial CHP is being addressed in the industrial model characterizations with the exception of the refinery sector, and is discussed further in Section 3.4 below. The SAGE-adapted approach used for EPANM and NE-MARKAL has been revisited and refined (disaggregated some). The state level representation of this approach that is to be employed for NE9/12 is nearly complete and ready for loading, including the fuel share user constraints controls specification tables (RATRULE ADRATIOs employing TechFilters). The approach used for industrial CHP extracts the fuel consumption data for on-site CHP use and apportions that to generic, sub-sector-specific CHP technologies. Careful attention and coordination with EPA will be required to determine how this approach may impact the characterization of the remaining industrial energy demands.
- Refinery sector represents a potential significant issue in that the AEO 2006 reference case projects 19GW of grid serving capacity coming out of the refinery sector from coal-to-liquids processes (CTL). Some discussion is still needed to decide the degree to which these combined electricity and liquid fuel generation plants are to be modelled in US9r and CTL plant output tied to the refinery sector. Additional information describing the NEMS approach to CTL was provided to EPA along with some references to potential data sources to assist in characterizing the technology. Additional discussion is still required before pursuing this element of the model further.³²
- While NEMS addresses non-traditional cogeneration as a CHP technology, the NEMS forecast for this segment is flat (see table above). The issue will be to understand how EPA is treating these facilities in their electric sector representation and to be sure not to double count or leave them out. A table characterizing the CHP that is included by EIA in its NEMS modeling has been prepared and delivered to EPA. Templates characterizing this segment of CHP have been assembled. Note, a major shortcoming of the NEMS

³² Latest comments received from EPA on July 18, 2006 indicates that this should be further discussed during the upcoming meeting in September.

characterization of these CHP units is the lack of data re the relative power to heat produced by the facilities. Our recommendation is to treat these facilities as though they were just another source of electricity and setting the REH value to an arbitrarily large number to effectively eliminate them as suppliers of non-electric energy services.³³

Appendix A provides a more detailed table of the NEMS AEO Reference Case CHP forecast by fuel, etc.

3.3.1 Workbook Organization, Data Sources and Transformations

The coupled heat and power workbook is constructed by means of an enhancement to NEMS data mining utilities developed by OnLocation for transforming key NEMS data files (inputs and outputs) for use in other modeling frameworks such as the EPA US9r.. In this instance these pre-existing capabilities were modified to deposit the desired data into a standard ANSWER “smart” workbook ready for loading. To this end the Commodity, Technology and Tech_Data_EHP sheets are constructed directly by means of the mining and transformation software. As such there are none of the traditional inter-relationships normally found in such workbooks where the TechData usually links back to the Commodity and Technology declaration sheet.

This “Smart³⁴” workbook contains 6 worksheets as follows:

- **ANSv5_Home**– This sheet defines the Answer template region handling and version information.
- **Assumptions** – *The principal assumption regarding the NT Cogeneration segment is that there will be little, if any expansion of this segment.* The historical regulatory structure that stimulated these facilities was repealed with the passage of the EPAct 1992 -- Energy Policy Act of 1992 which introduced the Exempt Wholesale Generators and eliminated the mandatory purchase of the electricity output of qualifying cogenerators. Select data definitions required making the following assumptions:
 - **Life:** These facilities were assumed to have a 40 year life and as such the “remaining” life, post 2000 was calculated and inserted into the template as the date the facility would be decommissioned.
 - **Seasonal/Annual Availability Factor:** Technology specific availability factors were established on a seasonal basis using the relative summer/winter net dependable capacity. If summer/winter net capacity were the same, the annual availability factor was used instead.
 - **REH:** (see discussion above and associated footnote) Since these facilities are assumed to be electricity generation, this value is being set to an arbitrarily high value indicating principal output is electricity.
- **Commodities** – Declaration sheet listing all the fuels involved in the CHP sub-system. Note that at the moment the coal types follow the basin naming convention set out in the coal sub-system, with the other fuels assumed to pass through a Xprc conversion sector

³³ This recommendation was accepted by EPA in their comments of July 18, 2006. The caveat is that their primary purpose is electricity generation (this is in line with the definition of non-traditional cogeneration). For now the electricity-to-heat ratio (REH) has been set to 999.

³⁴ Underlined worksheets correspond to actual load sheets handled by ANSWER by means of CheckSheet and Import from Excel.

collection process (resulting in ELC<fuel>) to track all non-coals consumed in the power sector.

- **Technologies** –Declaration sheet listing all the coupled heat and power plants. The names of these existing plants are derived directly from the source data.
- **Tech Data EHP**– The core data needed to depict the existing utility CHPs as extracted from NEMS data sources and transformed into their MARKAL equivalent parameters are deposited here.
- **Tech Data-FuelPRC**– This worksheet is currently empty as it is assumed that the Xprc structure for the power sector will be developed for the electric generation sub-system in said workbook. If this is the case this sheet can be deleted from this workbook, so it is viewed of as just a placeholder for now.

As already noted there is really no flow of data in this workbook, rather the data is extracted from the NEMS data sources, transformed, and deposited in MARKAL compatible format in the workbook. Transformations were minimal and primarily consisted of converting units to PJ/GWe and heatrates to energy input/energy output ratios. Input commodities were associated with each technology (see above regarding assumptions for additional discussion of transformations

3.3.2 Coupled Heat and Power Structure

In US9r coupled heat and power technologies in each region will produce electricity and heat for local consumption using the fuels available to the region once they have passed through the appropriate exchange processes, or refinery. This RES structure is depicted in Figure 17 below.

3.3.3 Areas for Possible Modification and Improvement

There may be a need to review and refine the commodity names feeding the individual CHPs. The level of detail contained in this workbook is extensive and probably would perform just as well if aggregated into groups by technology and fuel. As requested by EPA, the maximum level of detail was provided to allow EPA to subsequent aggregate, if desired.

3.3.4 Updating the Workbook

Since the data are provided on a facility specific basis, to update this workbook changes can be made manually, otherwise the NEMS-2-MARKAL extraction and transformation utility needs to be rerun by OnLocation. Note, this data mining activity can produce grouping of technology/fuel or other groupings based on user inputs. (See above regarding possible improvement.)

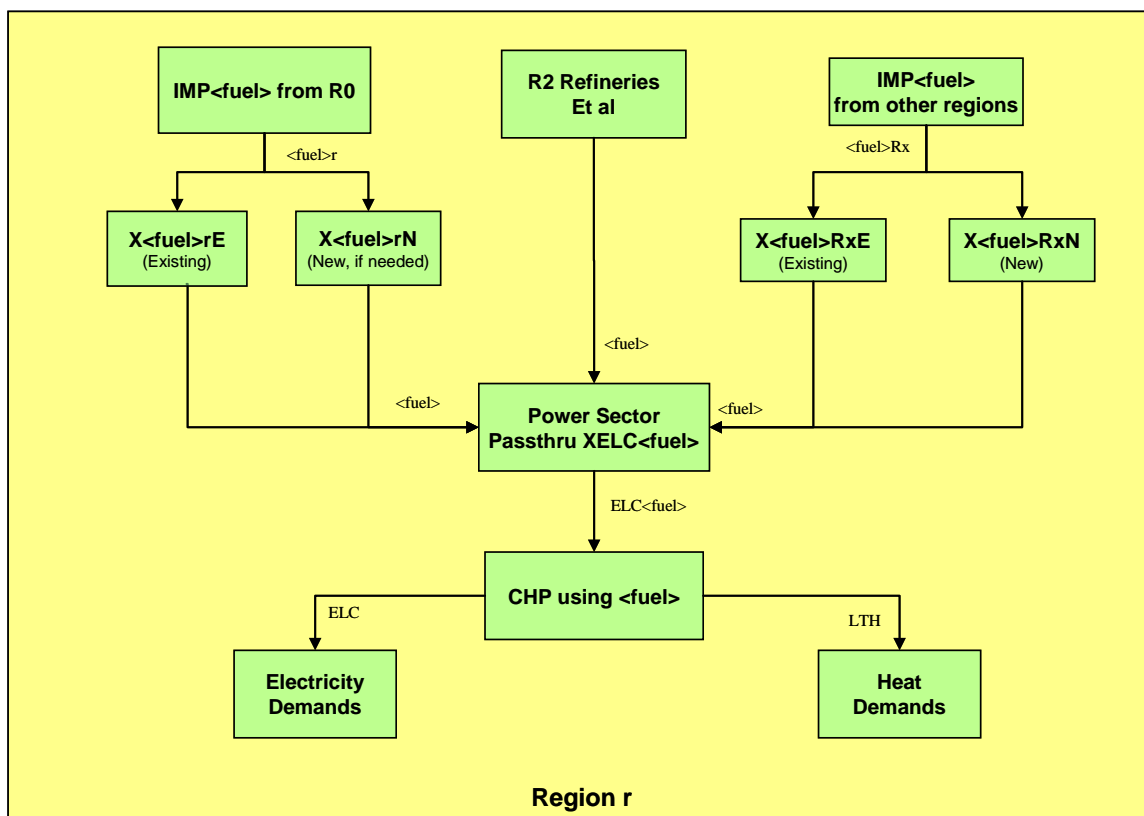


Figure 17: Coupled Heat and Power RES Structure

3.4 Industrial Sector CHP

Only the data development sections of this preliminary “Smart” workbook have been completed. The full development of the workbook will be dependent on EPA definition of the industrial sector demands and decisions on how various industry sub-sectors will be aggregated (or not). Therefore, the work under this contract has focused on development of the final energy consumption for industrial CHP in each demand region for the industry sub-sectors as defined in NEMS.

The methodology and data sources for industrial CHP are summarized in Figure 18. It should be noted that the data development for CHP can also support development of the industrial sector demand. The work to date is all above the heavy line. The work remaining (below the line) is dependent on EPA development of the industrial model and the industry sub-sectors that will be modeled.

3.4.1 Data Sources and Transformations

The NEMS Industrial Model provides breakouts of energy use for 15 industry sectors and refineries for the 4 Census regions³⁵ by fuel type. The data development starts with the NEMS final energy consumption data for each Census region as detailed in the NEMS regional

³⁵ Northeast, South, MidWest and West.

industrial tables³⁶ for 2002. This file provides fuel use data for each industry sector broken down into buildings, processes, steam/cogeneration and electricity generation. This data was collected into a subset of fuel categories that more closely matched the SEDS data and that are more appropriate for model use.

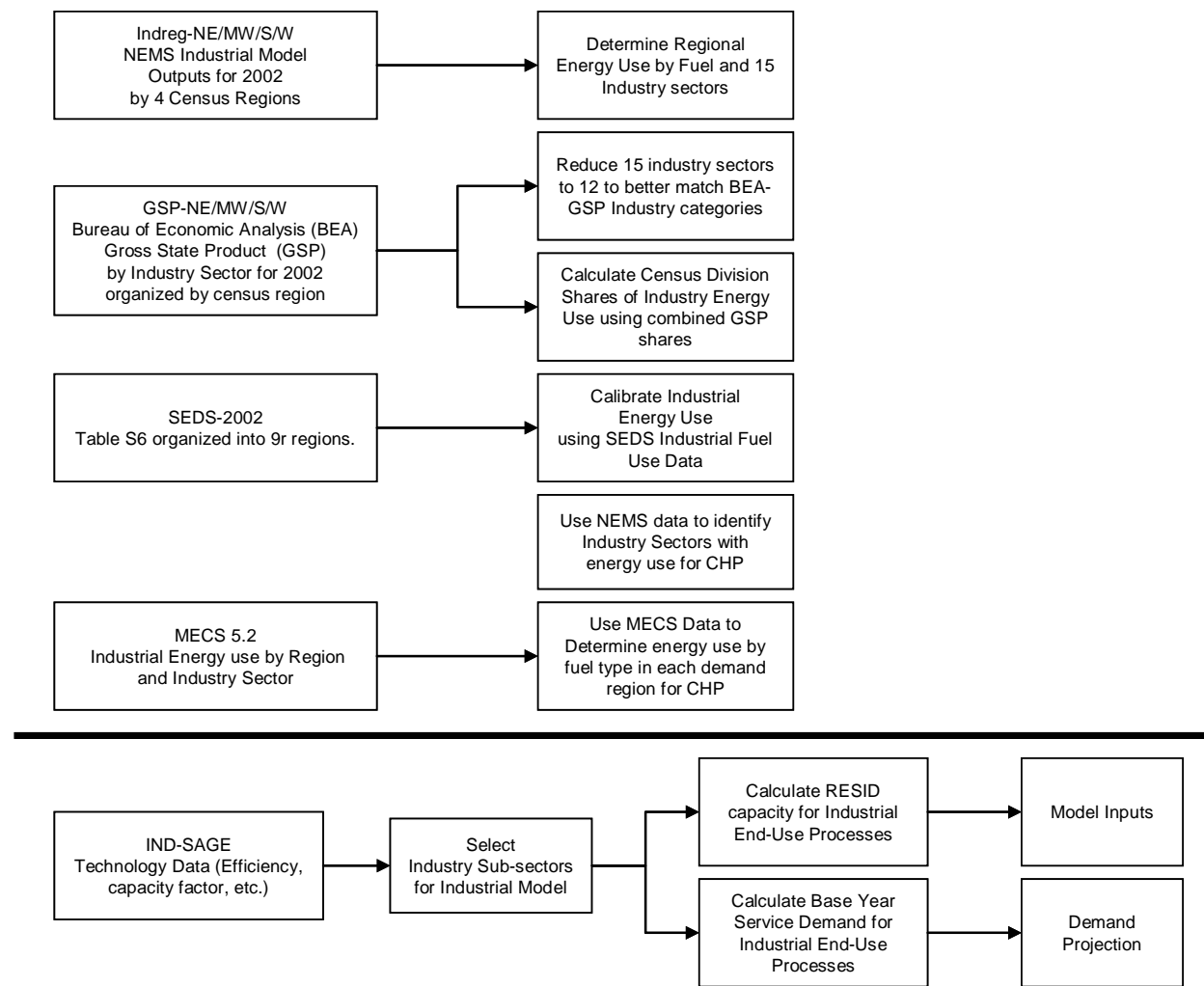


Figure 18: Industrial CHP Methodology and Data Sources

The Census region tables of industrial energy consumption by fuel type were separated into demand region shares of industrial energy use using the data from the Bureau of Economic Analysis (BEA), which provides Gross State Product (GSP) data for a large number of industries by NAICS code. The 2002 GSP data, available from the BEA - Regional Economic Accounts³⁷, was aggregated to the demand region level and used to determine demand region shares of

³⁶ See file: NEMS Industry_regional.xls

³⁷ See <http://www.bea.gov/bea/regional/gsp/>

energy use for each industry sector based on the assumption that industrial energy use is proportional to industrial economic output.

The NEMS industry categories were mapped by their NAICS codes to match the NAICS codes used in the BEA breakdown. Next, the state-level industry sector energy use shares - obtained by applying the state industry GSP shares to the regional industry sector values - were calibrated to the final energy use numbers provided in the SEDS industrial sector energy consumption table. The workbook had been initially developed using the SEDS 2001 data, but it has now been updated to use the recently released SEDS 2002 data³⁸.

MECS data³⁹, which provides national-average end use energy consumption by end-use type for a variety of industries by NAICS code, was used to develop CHP shares for each industry sector and fuel type. These shares were applied by region-level industry sector energy use to get base year final energy use for CHP by state, industry sector and fuel type.

EPA could also use the MECS data to develop base-year industry sub-sector demands by end-use and fuel type for the applications of boiler steam, process heat, machine drive, electrochemical process and other uses. These shares could be then applied to the region-level industry sector energy use to get base year final energy use by region, industry sector, fuel type and end-use.

3.4.2 Organization of Preliminary Workbook Data

The industrial CHP workbook contains 20 worksheets as follows:

- **ANSv5_Home**– This sheet defines the Answer template region handling and version information.
- **Commodities** – Input and output energy carriers (currently blank).
- **Technologies** – All industrial CHP technologies (currently blank).
- **Tech Data CHP** – Model input data (efficiencies, costs, residual capacities, and investment bounds) (currently blank).
- **IND-SAGE** – CHP and industrial process technology cost, efficiency and other data for use once the US9r industrial model is specified.
- **SEDS 2002** – SEDS Table 6 with final energy use data summed by demand region.
- **MECS-5.2** – 2002 end-use fuel consumption by NAICS code and fuel type.
- **indregNE** – NEMS data on industrial final energy use by 15 industry sub-sectors for the Northeast Census region.
- **NE Energy** – The main worksheet for the demand regions in the Northeast compilation of the NEMS energy use data by fuel type and industry sub-sector, splitting into demand regions according to BEA shares, adjustment to match the SEDS data by demand region, and calculation of CHP fuel use shares based on MECS data.
- **GSP-NE** – BEA⁴⁰ data for 2002 of Gross State Product by NAICS code for the states in the Northeast Census region – aggregated for each demand region.

³⁸ SEDS Table S6: Industrial Sector Energy Consumption Estimates, 2002.

³⁹ MECS Table 5.2: End Uses of Fuel Consumption within NAICS Codes, 2002.

⁴⁰ Bureau of Economic Analysis - Regional Economic Accounts - <http://www.bea.gov/beat/regional/gsp/>

- **indregMW** – NEMS data on industrial final energy use by 15 industry sub-sectors for the Midwest Census region.
- **MW Energy** – The main worksheet for the demand regions in the Midwest compilation of the NEMS energy use data by fuel type and industry sub-sector, splitting into demand regions according to BEA shares, adjustment to match the SEDS data by demand region, and calculation of CHP fuel use shares based on MECS data.
- **GSP-MW** – BEA data for 2002 of Gross State Product by NAICS code for the states in the Midwest Census region – aggregated for each demand region.
- **indregS** – NEMS data on industrial final energy use by 15 industry sub-sectors for the Northeast Census region.
- **S Energy** – The main worksheet for the demand regions in the South compilation of the NEMS energy use data by fuel type and industry sub-sector, splitting into demand regions according to BEA shares, adjustment to match the SEDS data by demand region, and calculation of CHP fuel use shares based on MECS data.
- **GSP-S** – BEA data for 2002 of Gross State Product by NAICS code for the states in the South Census region – aggregated for each demand region.
- **indregW** – NEMS data on industrial final energy use by 15 industry sub-sectors for the West Census region.
- **W Energy** – The main worksheet for the demand regions in the West compilation of the NEMS energy use data by fuel type and industry sub-sector, splitting into demand regions according to BEA shares, adjustment to match the SEDS data by demand region, and calculation of CHP fuel use shares based on MECS data.
- **GSP-W** – BEA data for 2002 of Gross State Product by NAICS code for the states in the West Census region – aggregated for each demand region.
- **Conv** – A list of conversion factors for use in the various data sheets.

3.5 Refineries

Discussions with the EPA during the model structure development phase of this project raised the following questions concerning refinery technology characterization:

1. The refineries in the EPA national model have flexibility in their output product mix, but emissions, costs, and refinery energy consumption are unchanged with changes in the product mix. EIA projects that refineries will continue to increase their production of light products (especially gasoline) relative to heavier products, and EPA model runs can be expected to generate significantly different refinery product mixes under different scenarios. How do changes in product mix affect emissions, costs, and energy consumption, and are these effects significant enough to attempt to model?
2. Are there refinery-related costs/constraints that should be modeled for producing products related to environmental policies, for example reformulated gasoline and ultra-low sulfur diesel?
3. The supply curves for imported crude, derived from NEMS, which we expect to continue to use, contain grade and sulfur content information. Currently, all of these crude supplies are collected before entering the refineries, with no use of the grade and sulfur

information. Are the effects on refinery costs and/or energy consumption of using different grades of crude significant enough for us to attempt to model? How do they vary regionally? Are emissions or costs higher when using higher sulfur content crude?

Our review of these issues has concluded that the size of these effects are small relative to other uncertainties in the analysis.

On energy consumption, refineries account for 3-5% of total US energy consumption over the AEO 2006 forecast horizon, and 11-15 % of transportation energy consumption. Thus even a change of up to 25% in refinery energy consumption will have only a minor effect on overall consumption. This suggests that changes in the scale of refinery operations could be significant in EPA's analysis, but changes in the internal specifications of these operations, through changes in product mix, are less likely to be.

On emissions, if we assume that refineries adjust operations to meet regulatory standards, there is unlikely to be any direct relationship between product mix and emission rates. As with energy consumption, the level of refinery operations is likely to be far more significant than product mix.

On costs, an EIA analysis⁴¹ has concluded that crude oil prices have been the most significant cause of the largest, long-term swings in product prices. Regional product price fluctuations of up to \$.50/gallon have been observed following the implementation of new requirements and refinery capacity outages, but these have generally been limited to six months in length or less. A National Petroleum Council study⁴² concluded that any supply disruptions and price volatility resulting from new fuel regulations were likely to be short-lived. Cost increases to produce low sulfur gasoline, low sulfur diesel, and reformulated gasoline without MBTE, including refinery capital and operating costs and distribution system costs, were estimated to be approximately five cents per gallon, well within the range of uncertainty resulting from crude oil price changes.

Concerning the use of different grades of crude, another EIA analysis⁴³ concludes that restrictions on refinery capacity and heavy crude conversion capacity have been overstated, and that US refineries have considerable flexibility in using different grades of crude.

Based on these conclusions, we have retained the EPA-NM refinery technology characterization in US9r, and have used NEMS data to regionalize it to the PADD level and update it to AEO 2006. In the event that refinery issues emerge as a major consideration in EPA's analysis, deeper study and revision of the design of the refinery sector could be considered as follow-on work.

Refineries are located in their respective Census regions, and are named PREF<E/N/L>, where E equals existing, N equals new, L equals the limit refinery that takes the dummy fuel to produce additional flexibility in light products. The refinery model retains all of the detail of the NEMS

⁴¹ Shore, J.(2002) Petroleum Outlook: Increased Inter-PADD Movements Expected. Presented at the API Annual Pipeline Conference, Dallas, Texas, April 2002.

⁴² National Petroleum Council (2000) US Petroleum Refining: Assuring the Adequacy and Affordability of Cleaner Fuels.

⁴³ Shore, J and Hackworth, J. (2005) 2004: Sign of the Future for Refiners? Presented at the NPRA Annual Meeting, March 2005.

output product stream. EPA may wish to aggregate some of these products, for example conventional and reformulated gasoline.

3.5.1 Workbook Organization, Data Sources and Transformations

The Refineries “Smart⁴⁴” workbook currently contains 15 worksheets as follows:

- **ANSv5_Home** – This sheet defines the Answer template region handling and version information.
- **Conv** – A list of conversion factors for use in the various data sheets.
- **PMM22-23** – NEMS Table 22x provides PSA Process Unit Capacity in MBCD for each PADD for a large number of products. Table 22y provides PSA Process Unit Utilizations, and Table 23a provides Refinery Capital Investment in Million \$ for each PADD. This data was used in calculating capital and operating costs on the Costs sheet.
- **PMM21-26** – NEMS Table 21 provides Electricity Purchased by refineries in each PADD in million kWh/cd, and Table 26 provides Refinery Fuel Use in MBFOE/cd for each PADD. This data is used to calculate refinery input energy carrier values on the Yield sheet.
- **PMM31** – NEMS Table 31 provides Refinery Production in MBCD for each PADD and 21 fuel types, used to calculate product output on the Yield sheet. This sheet also contains lines copied in from Tables 21, 26, 34 in order to facilitate calculations on the Yield sheet.
- **PMM34** – NEMS Table 34 provides Crude Input Volumes in MBCD for each PADD in terms of Domestic (Lower 48), Alaska and Imported supplies. This data was used to calculate product out relative to crude in on the Yield sheet
- **PMM50** – NEMS Table 50 provides Refinery Financial Information, Million \$, for each PADD, used in calculating capital and operating costs on the Costs sheet.
- **Yield** –Calculates INP(ENT)p and OUT(ENC)p for each PADD.
 - **INP(ENT)p**: There are three major input streams to refineries modeled in US9r: petroleum (including crude oil, and other petroleum feedstocks and fuels), natural gas, and electricity. In AEO 2006, inputs of crude oil and other petroleum per unit of total output fluctuate by PADD and year. This variation is due to variations in inputs of blending components, unfinished oils, and other fuels and feedstocks that are not captured in the simplified MARKAL refinery infrastructure. However, averaged over PADDs and years, the ratio of petroleum input to petroleum products output on energy basis does not differ significantly from 1. Therefore, INP(OIL) is not changed from its EPA-NM value of 1.
 - Inputs of natural gas and electricity also vary by PADD and year. Variations over the forecast horizon within a PADD are larger than those between PADDs, and are likely driven by specifics of the AEO forecast. Therefore INP(INDNGA) and INP(INDELC) are set to their average value over PADDs and years.

⁴⁴ Underlined worksheets correspond to actual load sheets handled by ANSWER by means of CheckSheet and Import from Excel.

- **OUT(ENC)p**: The maximum output of each product in the forecast horizon is calculated for each PADD. For existing refineries, OUT(ENC)p is set to 1.1 times this maximum, in order to allow for only limited flexibility. For new refineries, cells AK39-41 control the flexibility over the maximum and the fraction of flexibility going to the new conversion and new limit refineries.
- **RESID** – Residual refinery capacity for each Census region. RESID values are calculated from state-level EIA historical data⁴⁵ aggregated to each region.
- **Costs** – Calculates refinery investment and operating costs for each PADD region. For capital costs, total investment costs over the forecast horizon are taken from Table 50. From this are subtracted all of the costs for CHP and coal to liquids related equipment, taken from Table 23, since these will be tracked separately in US9r. This value is divided by total capacity additions, taken from Table 22, to arrive at capital cost per unit of additional capacity. The capital cost is regionalized using regional fractions from the NEMS documentation. Operating costs are taken from Table 50 and divided by capacity from Table 22 to calculate regionalized fixed operating costs per unit of capacity.
- **Emissions** – Data sheet with refinery emission factors for carbon, sulfur, NO_x, VOC and particulates. Emission factors are retained from EPA-NM and were originally derived from a model for refinery emissions developed by Delucchi (2003)⁴⁶.
- **Commodities** – Input and output energy carriers for all refinery technologies.
- **Technologies** – Three refinery technologies for existing conversion characteristics, new conversion characteristics and new limit characteristics.
- **Tech Data** – Model input data (efficiencies, costs, residual capacities, and investment bounds) for all refinery types in each demand region.
- **Tech Data ENV** – Model input data for refinery emissions coefficients.

3.5.2 Refineries RES Structure

As shown in Figure 19, the crude oil supply from all sources and PADDs can in principal supply the refineries within a demand region through their respective X transport processes. The arrangement of the New Conversion and the High Limit refineries allows maximum flexibility of the production of various refined products. Refinery products are traded as described above in Section 2.2.

⁴⁵http://www.eia.doe.gov/oil_gas/petroleum/data_publications/petroleum_supply_annual/psa_volume1/psa_volume1.html

⁴⁶ Delucchi, MA.(2003) A Lifecycle Emissions Model (LEM): Lifecycle Emissions from Transportation Fuels, Motor Vehicles, Transportation Modes, Electricity Use, Heating and Cooling Fuels, and Materials -Documentation of methods and data- MAIN REPORT, December 2003, Institute of Transportation Studies, University of California. <http://www.its.ucdavis.edu/publications/2003/UCD-ITS-RR-03-17-MAIN.pdf>

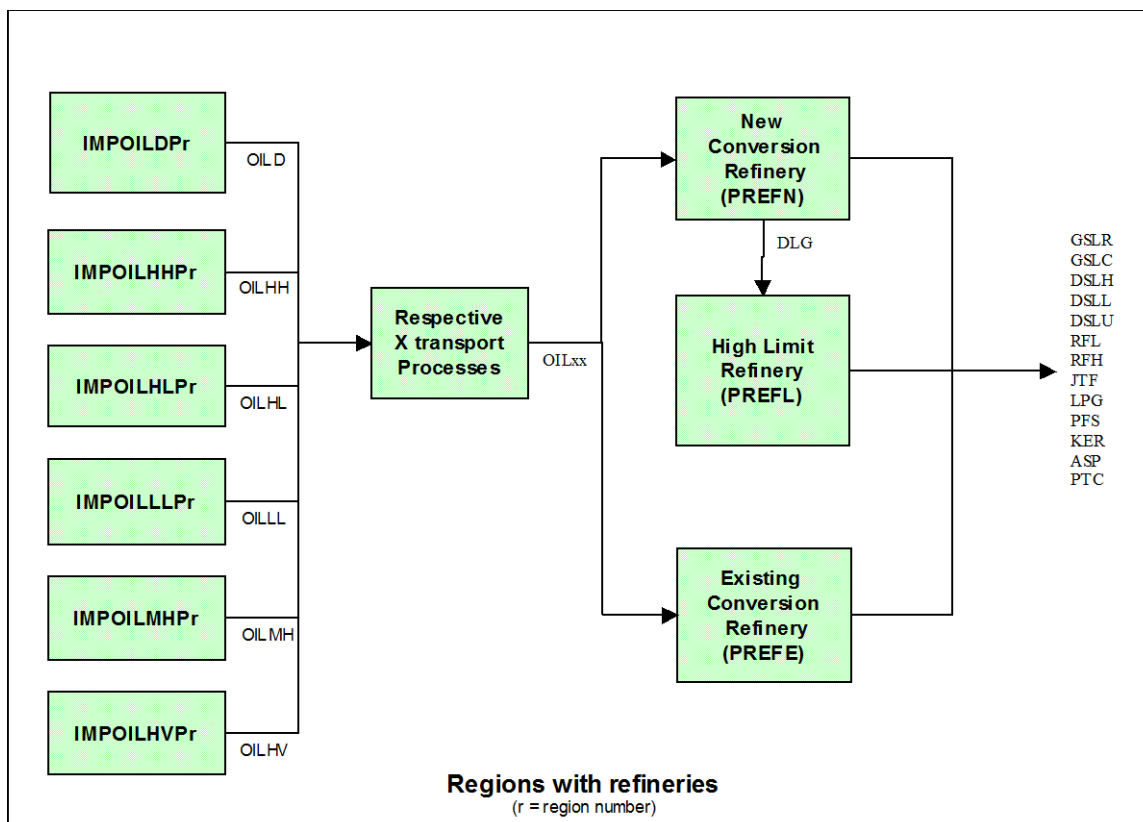


Figure 19: Refinery RES Structure

3.5.3 Areas for Possible Modification and Improvement

In the process of our review of the EPA-NM structure, we considered two possible refinery model structures that might be used to address the issues raised above. The first was described in the first draft of this document. The second is the refinery subsystem from the Italian MARKAL model, provided by GianCarlo Tosato. Like NEMS, the Italian refinery model represents dozens of individual refinery processes, including distillation, coking, thermal cracking, and hydrocracking, and several different grades of crude inputs. More information on the Italian refinery model is available upon request.

Our review of these model structures and the input and output data available from the NEMS Petroleum Market Module (PMM) indicates that these more complex structures cannot be used without significant post-processing of NEMS data, and focused runs and output dumps from the PMM. Combining this observation with the conclusions described above, that the effects that could be captured with such structures are smaller than other uncertainties in the analysis, has led us to conclude that current methodology was the better course for developing US9r at this time. However, it may be possible to develop a refinery model of intermediate complexity. Skip Laitner and Don Hanson's AMIGA model and other analysts at DOE are possible sources for refinery structures and data for such an endeavor. Whether improvement of the refinery model is warranted or not will depend on the anticipated size of uncertainties generated by refinery model structure relative to other uncertainties in the EPA analysis.

One modification that may prove necessary upon model integration and testing is an adratio constraint controlling the relative shares of varying grades of crude input into the refineries.

Without such a constraint, the model may make unrealistic purchases of cheaper, heavier grade crude. Data from NEMS to support development of this constraint is available upon request.

3.5.4 Updating the Workbook

Updating the refinery model to future Annual Energy Outlooks will require obtaining the relevant PMMRPT tables and in putting them into the workbook structure. (These tables are not part of the public release files, but are an internal report generated by NEMS, which should be available upon request from EIA.) Care will need to be taken that the link structure is preserved, particularly if the PMMRPT table structure changes. However, since many of the values calculated are averages (or maxima) over the AEO forecast horizon, they can be expected to change little in future AEO's, barring major changes in the NEMS refinery model structure or in the anticipated petroleum market, so updating may be less crucial than in other sectors.

4. Flexible Timeslices: Towards More Detailed Electricity (and Heat) Modeling in MARKAL⁴⁷

4.1 Basic Goal

Probably the single biggest restriction, and thereby shortcoming, in MARKAL since its inception is that it imposes a fixed segmentation of the electricity load curve by dividing the annual demand for and production of electricity into six (6) distinct time-slices, and three (3) seasonal splits for heat.

The time-slices are managed by means of three sets, a primary Season+Time-of-Day set TD(Z,Y), composed of Z corresponding to the seasons {I=Intermediate, S=Summer, W=Winter}; and Y corresponding to diurnal divisions {D=Day, N=Night}, and TD is thus a 6-tuple resulting from the combination of Z+Y, such that TD = {ID, IN, SD, SN, WD, WN}. This convention (and limitation) is embedded in the MARKAL code in that there are specific tests and handling of model components based upon certain long-standing conventions that the expanded representation will have to accommodate, as discussed later.

The goal of the current enhancement is to partially redress this limitation by allowing the user to enumerate the elements of the sets Z and Y (and thereby TD), but to do so without otherwise changing the basic depiction and operation of the power sector (electricity and heat) in the model. That is the basic parameters, equations and variables of the model are not be changed, but rather just expanded in terms of the number of time-slice instances handled.

4.2 Some Implicit Assumptions

The user who wishes to stick with the existing time-slicing ($Z = \{I, S, W\}$; $Y = \{D, N\}$) will be able to do so without any changes to their current datasets. That is the enhancement will be backward compatible with existing models. Those looking to expand the time-slice representation will not only have to provide the list of the elements (and descriptions) in each of the time-slice Sets but, as discussed in the next section, will also have to provide additional switches and Sets to enable the model code to properly recognize the nature of the various time-slices.

Flexible time-slicing in MARKAL requires that both the GAMS-MARKAL code and the user interfaces for working with MARKAL (ANSWER and VEDA-FE) be enhanced to allow the user to flexibly specify the time-slicing. The implications/mechanisms to enable support for more flexible time-slicing in ANSWER are presented in Appendix A. *{VEDA-FE already handles open time-slices for TIMES, so is expected to be able to be easily adapted to support the new MARKAL/SAGE time-slice formulation when desired/requested to do so. However it does not support the current implementation at this time.}*

A restriction is placed on the user with respect to the expanded TD(Z,Y). The names of each of the individual elements of the time-slice sets Z and Y are to be composed of up to 3 alphanumeric characters (A-Z, 0-9), starting with an alphabetic character.

⁴⁷ ANSWER/MARKAL system documentation updated in MARKAL_ANSWER-TD(ZY)+RATRULE-TechFilter (5).DOC.

4.3 Implications for the User

As already noted a user who wishes to stick with the existing time slicing will not have to make any changes to their current datasets to run with the new code. But for users looking to expand the time-slice representation, since MARKAL has embedded knowledge with respect to the meaning of certain time-slices (e.g., 'D' = day or peak time, 'N' = night or off-peak time) the "equivalent" knowledge will need to be passed to the model by means of new sets and switches. More specifically, MARKAL needs to know the one daily division corresponding to the time during which storage may occur (e.g., pumped hydro, night storage device) and the baseload constraint is to be imposed (YNITE, default Y='N'). The other consideration imposed by the current MARKAL code is the way that baseload technologies (BAS(CON)) are modeled using a single variable (Y='D') for annual production apportioned to each time-slice according to the QHR fractions, and that some associated data may be tied to. As a result the user will also be asked to identify the one daily division to be used for the baseload variables (YBAS, default = 'D').

As a result, for a model involving an expanded time slice representation, the ANSWER and VEDA-FE shells will need to allow the user to manage the following SETs.

- Y - the Set listing all the divisions of the day, with descriptions {default = D,N}
- YDAY - the divisions of the day other than YNITE {default = D}
- YPEAK(Z,Y) - the Set identifying the timeslices for which peak capacity equations are to be generated, defined on the Global tab⁴⁸ (or the TimeSlice tab) {default = S.D, W.D}
- Z - the Set listing the seasons, with descriptions {default = I,S,W}
- TD(Z,Y) - the Set comprising the 2-tuple list of the combination of (all desired) Z,Y {default = I.D, I.N, S.D, S.N, W.D, W.N} [Note, not under user control assembled from the combination of Z,Y, though the user may remove tuples if desired.]

Furthermore the expanded time-slice representation requires that the following new switches be included in the GEN file(s).

- \$SET NEWTD - a switch set to 'YES' to initialize the model for extended time-slices, disabling the traditional initialization of Z, Y and TD {default = none}
- \$SET YBAS - the one division of the day (not YNITE) to be used for the baseload variables {default = D}
- \$SET YNITE - the one division of the day to be considered the night (when storage may take place and the baseload constraint is applied) {default = N}

At the current time YBAS/YNITE need to be the same for all regions of a multi-region model⁴⁹. The YBAS/YNITE indicators, which in ANSWER are entered from the new TimeSlice tab via the Additional Characterization sub-form, serve these three important purposes:

⁴⁸ When the user does not provide YPEAK(Z,Y) it will be set to all YDAY for each season (Z).

⁴⁹ If it is decided that the TD(ZY) definition may vary between regions then some adjustments will be needed to the GAMS code, and to ANSWER where the operation of the TimeSlice tab assumes that the same Time Slice structure

1. The storage issue is handled cleanly, in that pumped and night storage technologies will only consume energy (electricity) during YNITE, which will also be the time-slice when the baseload constraint will be applied. These storage technologies will then only release said energy during non-YNITE slices. Note that the storage YNITE consumption level will be determined according to the sum of the production from all the other time-slices.
2. The baseload technologies are tied to the YBAS time-slice and the operation in the other time-slices derived from the annual production represented by that lone variable, as is the case now. This results in the plant operating in all Y if it operates at all in a season (Z).
3. The structure of the current MARKAL code can accommodate this approach with many straightforward changes, rather than more complicated coding (that would slow performance). The only equation directly affected is the electricity peaking constraint (EQ/MR_EPK), which will now pick-up the Y index, and is generated for each YDAY for each electricity energy carrier (ELC) for which a reserve margin (ERESERV) is provided.

For a model involving an expanded time-slice representation, the ANSWER and VEDA-FE shells will ensure that the GEN file(s) have \$SET NEWTD = 'YES' (perhaps requiring one-time user editing of the GEN/SLV Templates). Since the Sets Z, Y, and TD(Z,Y) are domain declaration sets in MARKAL, they **must** appear prior to any related declarations in MMINIT.INC, with Sets Z, Y before TD(Z,Y). The \$SET YBAS and \$SET YNITE may then immediately follow. When \$SET NEWTD is not provided the code will properly initialize these sets according to the current paradigm (the defaults) for existing models. When \$SETNEWTD = 'YES' is provided the traditional declarations are avoided and the user-defined information established instead.

4.4 Handling Electricity Trade in Multi-region Models

In multi-region MARKAL bi-lateral trade in electricity introduces a new time sliced supply variable (R_TSEPE(REG,TP,IE,ELC,P)), where the IMPort and EXPort variables are lined up according to the common trade route indicator (P), though the ELC names may differ in each region. These time sliced electricity trade variables are then used in place of the traditional annual supply variable (R_TSEP) in the various electricity related equations (MR_BALE, MR_EPK and MR_BAS) as well as the objective function. The aggregate annual variable is equated to the sum of the time slice exchanges and used elsewhere in the model (e.g., emissions accounting if appropriate).

There are two important considerations related to electricity trade in multi-region models:

- matching up the names of the TD(Z,Y) in each region, and
- the problem of depicting the timing of the electricity generation and demand across the regions.

To handle these a rather straightforward compromise approach has been discussed and agreed upon (by those responding) to address both. The TD(Z,Y) will be the same in each region and the timing of the generation and demand will be based upon the time in a single time zone. Therefore when working in the US if Eastern Standard Time (EST) is used the shape of the load

(though not parameter values) applies for all regions. See the discussion in Section 1.4 and Appendix A.7 on handling electricity trade in multi-region models.

on the west coast would be shifted by 3hrs. Thus a “true” west coast 4pm demand would be moved into the 7pm time-slice. This will permit the modeling of trade in electricity as part of looking to meet non-concurrent peaks in the regions, where the infrastructure exists or can be built.

4.5 Model Components Affected by the New Formulation

The individual parameters, equations and variables impacted by adding flexible time-slicing to the GAMS-MARKAL code are identified here, and any special consideration noted. The information provided here indicates the single region version of these model components, with the exception of the bi-lateral electricity trade equation and variable. For multi-region models each of the components picks-up a REG index in the first position, the EQ_ equation prefix is replaced by MR_, there is a R_ prefix added to the variables, and a _R is appended to the parameters names. For those parameters, equations and variables where Stochastics applies an SOW index is inserted, a MS_ prefix used for equations, and an S_ prefix for the variables and parameters.

4.6 GAMS-MARKAL Sets and Parameters that have time-slice references

In addition to the core Z, Y, and TD sets, and the new sets and switches mentioned previously, these sets and parameters are impacted by the expanded formulation. However, the only implication is that more (less) instances of Z,Y may be provided.

CPD_CEH(CPD,Z,Y)	Electricity lost pre unit of heat for pass-out turbines
CPD_TEFF(CPD,Z,Y)	Trans. eff. loss for heat from central CPD plants
DHDE(Z,LTH)	District heating seasonal distribution efficiency
DM_FR(DM,Z,Y)	Seasonal Fraction of Demands
HEATCOOL(Z)	Season(s) for which the heat peaking constraint is built
QHR(Z,Y)	Season/Time-of-Day Fractions
RAT_TZYZ(ADRATIO,CON,Z,Y,YEAR)	Ratio coef. for Electric production variable
RAT_TCZY(ADRATIO,CPD,Z,Y,YEAR)	Ratio coef. for Coupled production heat variable
RAT_HPL(ADRATIO,HPL,Z,YEAR)	Ratio coef. for Heat. Production variable
SEP_FR(SRC,ELC,P,Z,Y)	Season/Time-of-Day for Electricity import/export
TCH_AF3(TCH,Z,Y,YEAR)	Seasonal Availability Factor for power plants
TCH_CF1(TCH,Z,Y,YEAR)	Seasonal Utilization Factor for power plants
TCH_PD(CON,Z,YEAR)	Peak duration factors
TCH_SRAF(TCH,Z)	Seasonal reservoir availability

Note also that consideration will need to be given to the other parameters that are related to the electric sector. Most notably PEAK(CON), PEAKDA(PRC/SEP) and PD(Z)D may pickup Z,Y indexes (as an option) to allow better modeling of peaking in different time slices. However this has not been done at this time.

4.7 GAMS-MARKAL Equations that have time-slice references

EQ_BALE(YEAR, ELC, Z, Y)	Bal. of electricity by season for day (=G=)
EQ_BALDH(YEAR, LTH, Z)	Bal. of low-temperature heat by season (=G=)
EQ_BALDH_S(YEAR, LTH, Z)	Bal. of low-temperature heat by season with slack

EQ_BAS(YEAR, ELC, Z, Y) Electricity prod. base-load constraints (=L=)
 EQ_TZY(YEAR, TCH, Z, Y) Electricity-prod. capacity constraint (ELA) (=L=)
 EQ_THZ(YEAR, HPL, Z) Heating-prod. capacity constraint (ELA) (=L=)
 EQ_EPK(YEAR, ELC, Z, Y) Electricity-peaking for (most) any time-slice (=G=)
 EQ_HPK(YEAR, LTH, Z) Heat-peaking for (most) any season (=G=)
 EQ_SRM(YEAR, HDE, Z) Seasonal reservoir constraint (=L=)
 MR_BITRDE(REG,TELC,REG2,YEAR,ELC,P,TD) Bi-lateral electricity trade (=E=)

Note that the EQ_EPK constraint will pick-up a Y-index (for the non-YNITE time slice), and the EQ_HPK constraint a Z-index, where HEATCOOL will list the seasons for which the LTH energy carriers are used for either heating or cooling.

4.8 GAMS-MARKAL Variables that have time-slice references

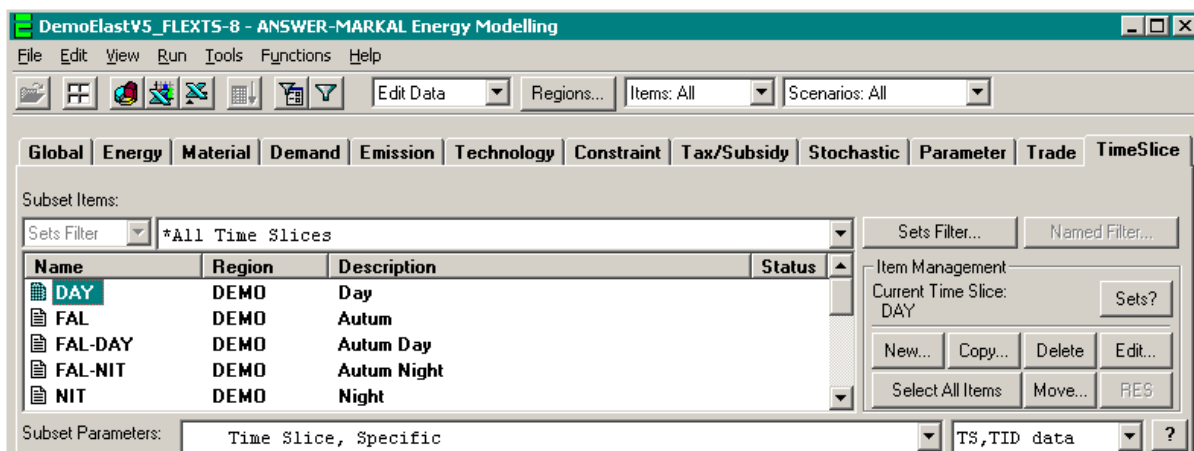
M(YEAR, CON, Z) Scheduled Maint. in a Season for a Conversion Technology
 TZY(YEAR, TCH, Z, Y) Annual Prod. of Electricity for each time-slice
 THZ(YEAR, TCH, Z) Annual Prod. of LTH for each Season from Heating Plants
 TCZYH(YEAR, TCH, Z, Y) Annual Prod. of LTH for each Season from CPD Plants
 SLKLTH(YEAR, ENT, Z) Slack variable in ENC_S balance
 R_TSEPE(REG,YEAR,SRC,ELC,P,TD) Time-sliced electricity exchange in/out of a region

Note that the operation of so-called baseload plants (e.g., nuclear), which forces a power plant to operating “continuously” during a season, will be keyed off the YBAS variable, adjusted according to the duration of the individual time-slices. That is only the YBAS variable will be generated representing the total electricity from a baseload plant in a season, where the contribution in each time-slice is determined by the QHR(Z,Y) / QHRZ(Z). Also, for storage technologies (STG, NST) the sum of the non-YNITE variables (YDAY) will be used to determine the electricity consumption requirements at night, thus there will be no YNITE variables for storage plants.

4.9 Handling Flexible Time Slices Under ANSWER

4.9.1 Overview

There is a new TimeSlice tab to the right of the Trade tab:



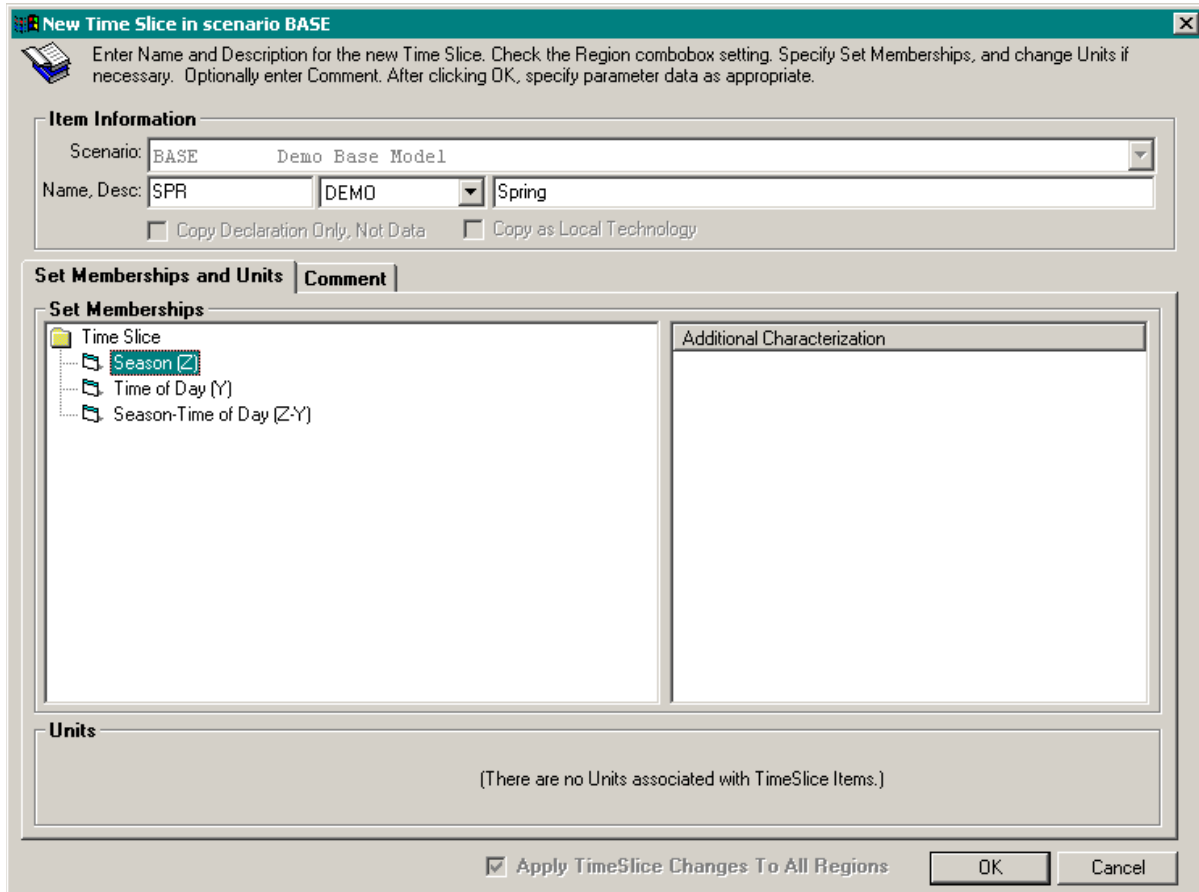
The following Time Slice subsets are provided, as shown by dropping down the “*All Time Slices” combobox:



While the same general mechanics are available for New/Copy/Delete/Edit Time Slice as on other tabs, a number of special considerations apply on the TimeSlice tab. These will be discussed shortly, but first let’s consider how to create a new **Season** Time Slice.

4.9.2 Creating a New Season Time Slice (Member of Z)

Click on the [New...] button and enter Name and Description for the new season, then click on the “Season (Z)” node of the Set Memberships tree.



Then click on the [OK] button. As noted above, additional special considerations apply that will be discussed shortly, but now let’s consider how to create a new **Time of Day** Time Slice.

4.9.3 Creating a new Time of Day Time Slice (Member of Y)

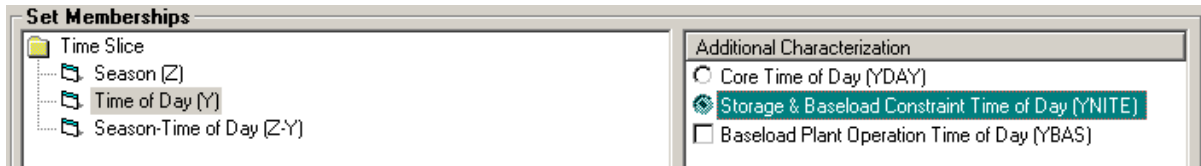
Click on the [New...] button and enter Name and Description for the new Time of Day division, then click on the “Time of Day (Y)” node of the Set Memberships tree. This displays a number of Additional Characterization options, which will be discussed shortly.

As on other ANSWER tabs, after selecting the appropriate Additional Characterization options, click on the [OK] button to save the new Time Slice to the database.

The two principal Additional Characterization alternatives – “Core Time of Day (YDAY)” and “Storage & Baseload Constraint Time of Day (YNITE)” – are provided by the radio buttons, with “Core Time of Day (YDAY)” selected by default.

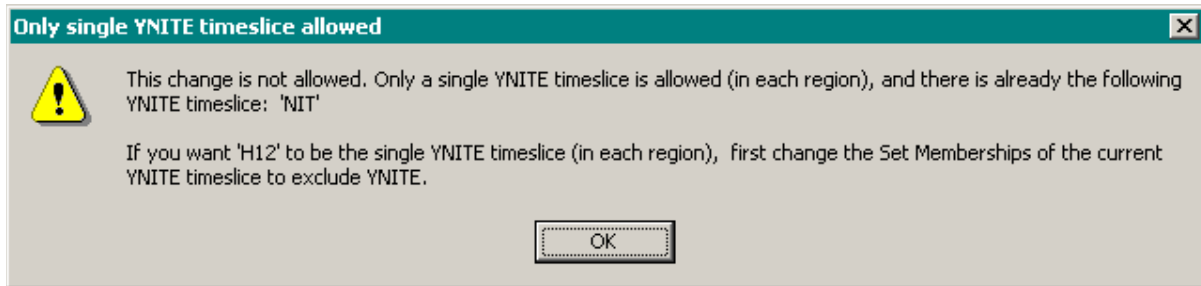
When YDAY is selected, the “Baseload Plant Operation Time of Day (YBAS)” checkbox is initially unchecked, indicating that this core Time of Day division is not to be used as the baseload variable division of the day (YBAS). To specify that this YDAY Time of Day division is the baseload variable division of the day, check the “Baseload Variable Time of Day (YBAS)” checkbox:

To specify that a Time of Day division is the division when storage takes place and the baseload constraint is applied select the “Storage & Baseload Constraint Time of Day (YNITE)” radio button:



Note that ANSWER ensures that only one Time of Day division Y is tagged as YNITE and that only one Time of Day division Y (YDAY actually) is tagged as YBAS. Thus to change a previously specified YNITE or YBAS the user must first deactivate the current selection in order to select a different one.

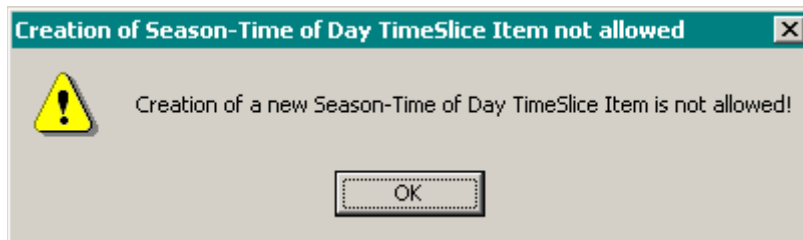
If the user tries to create a second YNITE Time of Day division, then the following message appears:



A similar message appears if the user tries to create a second YBAS Time of Day division.

4.9.4 Creating a new Season-Time of Day Time Slice (Member of Z-Y)

Since a mechanism is provided which automatically generates the Season-Time of Day timeslices from the Season and Time of Day Time Slices this option is prohibited, see below. If the user having invoked “New...” clicks on the “Season-Time of Day (Z-Y)” node in the Set memberships tree, the following message appears:



4.9.5 Additional special considerations applying to the TimeSlice tab

As can be seen from the above examples of what is involved in creating new Season and Time of Day Time Slices, the same general mechanics apply on the TimeSlice tab as on other tabs. Below is a list of additional special considerations that have been incorporated when carrying out New/Copy/Delete/Edit Time Slice:

1. Name is restricted to be at most 3 alphanumeric characters with the first character required to be alphabetic, for both Season and Time of Day.

2. Description is restricted to be at most 40 characters, for both Season and Time of Day. (The Description for each Season-Time of Day Time Slice is automatically generated by concatenating the Season description and the Time of Day description, see 3, and so we need to ensure that the result of concatenating does not exceed ANSWER's limit on Description length.)
3. The Season-Time of Day Time Slices (Z-Ys) are automatically generated from the Season (Z) and Time of Day (Y) Time Slices. This is because proper operation of ANSWER and the ANSWER-specific parts of the GAMS-MARKAL code requires that each Name in set Z-Y comprises a Name from set Z and a Name from set Y, concatenated with a hyphen. This means that the following considerations also apply:
 - The user is not allowed to create new members of set Z-Y. (Though the user may *delete* members of set Z-Y to restrict to a subset of the full set of Z-Y possibilities.)
 - If the user creates a new Season say **AUT**, then new members corresponding to **AUT-Y** are automatically created for each existing Time of Day division Y.
 - Likewise, if the user creates new Time of Day division say **H12**, then new members corresponding to **Z-H12** are automatically created for each existing Season Z.
 - If the user *edits* the Name of a Season or a Time of Day division, then the Names of members in set Z-Y and all associated data parameter instances are automatically adjusted.
 - If the user *edits* the Description of a Season or Time of Day division, then the Descriptions of related members of set Z-Y are automatically adjusted.
 - If the user attempts to *delete* either a Season or a Time of Day division, after putting up an appropriate cautionary message and getting the user's confirmation of the delete, the related members of set Z-Y and all associated data parameter instances are deleted.
 - Only changes to Additional Characterization are allowed, that is a change from "Season (Z)" to "Time of Day (Y)" (or vice-versa) is disallowed. A corollary is that a user who gets this aspect of Set Memberships wrong when creating a new Time Slice will need to delete the Time Slice and recreate it via "New Time Slice".
4. Time Slices should be defined in the BASE scenario only.
5. It is the user's responsibility to provide the appropriate Time Sliced data parameters for each of the relevant Time Slices.

4.9.6 Setting the Peak Time Slices

The user may establish the Time Slices for which peaking constraints are to be established by explicitly identifying them on the Global tab (or the TimeSlice tab) via the PEAK(Z,Y) TID parameter. That is, use the AddRow facility to add PEAK(Z,Y) parameter instances for the Time Slices for which peaking constraints are desired.

Scenario	Parameter	Region	TimeSlice	Value
BASE	HEATCOOL(Z)	? DEMO	WNT	1
BASE	PEAK(Z)(Y)	? DEMO	SUM-DAY	1
BASE	PEAK(Z)(Y)	? DEMO	WNT-DAY	1
BASE	QHR(Z)(Y)	? DEMO	FAL-DAY	0.1250
BASE	QHR(Z)(Y)	? DEMO	FAL-NIT	0.1250
BASE	QHR(Z)(Y)	? DEMO	SPR-DAY	0.1250
BASE	QHR(Z)(Y)	? DEMO	SPR-NIT	0.1250
BASE	QHR(Z)(Y)	? DEMO	SUM-DAY	0.1250
BASE	QHR(Z)(Y)	? DEMO	SUM-NIT	0.1250
BASE	QHR(Z)(Y)	? DEMO	WNT-DAY	0.1250
BASE	QHR(Z)(Y)	? DEMO	WNT-NIT	0.1250
BASE	STARTYRS	? DEMO	-	5.0000
Add	BASE	?		

Database: C:\Answer\5beta\Answer_Databases\DemoElastV5_FLEXTS-8 | Edit Scenario: BASE

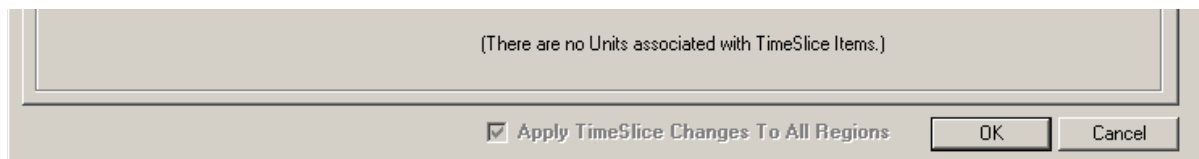
When no PEAK(Z)(Y) is provided (corresponding to YPEAK in the MARKAL GAMS code) it is initialized to all YDAY in each Season. Note that it is the user's responsibility to ensure that the Time Slice in which the highest daytime demand occurs is included among the PEAK(Z)(Y) entries.

4.9.7 Multi-region Considerations for Flexible Time Slicing

In the screen snapshots at the beginning of this Appendix it can be seen that Time Slices occur with a Region association – in this case for region DEMO. To avoid major changes to ANSWER fundamentals Time Slices – like other Items in ANSWER – need to occur with a Region association.

However, since it is required that the Time Slice structure is identical in all respects in all regions of a multi-region model (*except* that Time Slice data values are region-dependent), the following additional considerations apply to multi-region models:

1. When the user creates a new Time Slice in a region, ANSWER automatically creates this Time Slice in *every* region. Likewise when the user edits a Time Slice in a region, ANSWER automatically applies the editing changes made to this Time Slice in *every* region. (The observant reader may have noticed the disabled but checked “Apply Time Slice Changes To All Regions” checkbox to the left of the [OK] button on the New/Copy/Edit Time Slice form.)



2. When the user deletes a Time Slice from a region, ANSWER automatically deletes this Time Slice from *every* region.
3. When the user creates a new region within a multi-region database, this new region will contain the (common) Season and Time of Day Time Slices that apply in the existing regions.

4.9.8 Run Model Considerations for Flexible Time Slicing

GAMS language considerations mean that for flexible Time Slicing, the Time Slice sets must be put out before any other declarations in \$INCLUDE MMINIT.INC. To meet this requirement, the ANSWER Run Model facility generates a special DDS file that contains just the Time Slice set information, and the Template.GEN and RegionTemplate.GEN files are adjusted to pass the name of this file to MMINIT.INC for inclusion prior to any other declarations.

The special DDS file containing the Time Slice set information is named <Run>_TS_<Region>.DDS, where <Run> is the Run (Case) name and <Region> is the region. For a multi-region run, one of these special DDS files is generated for each region that is involved in the run.

For a single-region run, the Template.GEN file is adjusted as follows (note the lines in the screen snapshot below that are bolded):

```

Template.gen - WordPad
File Edit View Insert Format Help
$TITLE NOBLE-SOFT ANSWER: CASE <Run>
OPTION LIMROW=0, LIMCOL=0, SOLPRINT=ON, SYSOUT=OFF, ITERLIM=200000;
OPTION RESLIM=50000, PROFILE=0, SOLVEOPT=REPLACE;
*OPTION NLP=MINOSS;
$OFFLISTING

* Uncomment if wanting to use flexible timeslicing
$SET NEWTD 'YES';

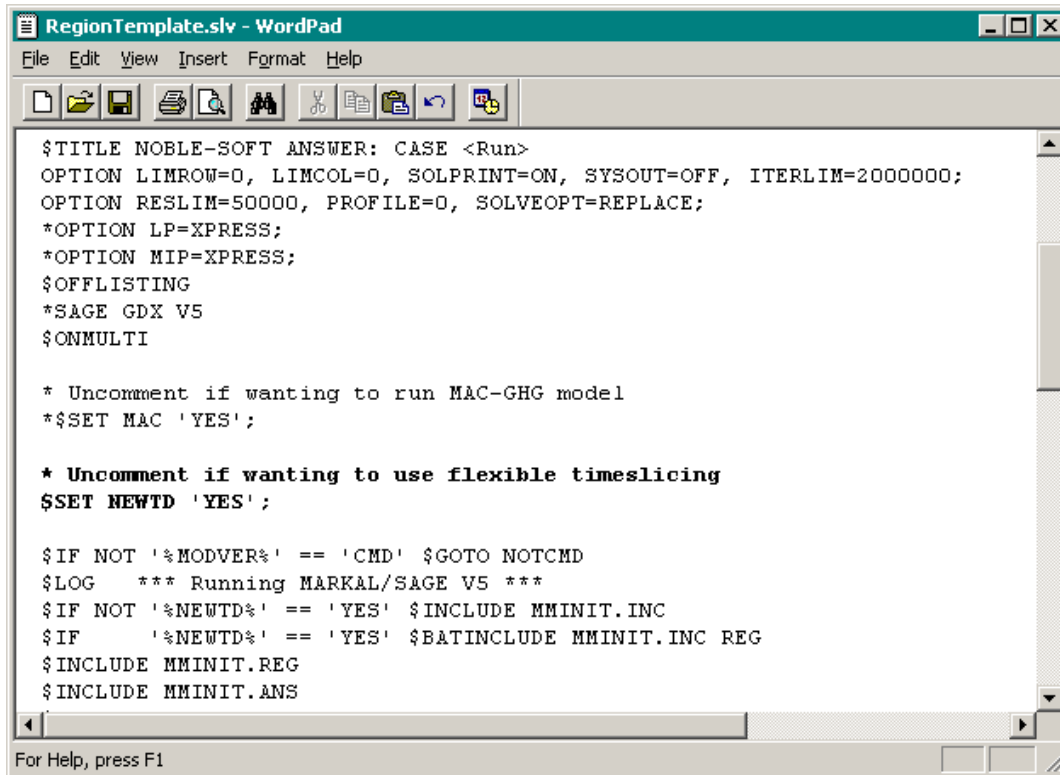
$IF NOT '%NEWTD%' == 'YES' $INCLUDE MMINIT.INC
$IF '%NEWTD%' == 'YES' $BATINCLUDE MMINIT.INC <Run>_TS_<Region>.DDS

$ONMULTI
$SET SHELL 'ANSWER';
$SET LUMPYINV '<LumpyInvestment>';
$INCLUDE MMINIT.ANS
*
SET SCENCASE / '<Run>' '<RunDesc>' /;
SET REG / '<Region>' /;
* include the .DD and .DDS files
<IncludeDDLines>
For Help, press F1

```

For a multi-region run, the RegionTemplate.GEN file is similarly adjusted.

In addition for a multi-region run, the RegionTemplate.SLV file is adjusted to \$SET NEWTD 'YES', and REG passed on the call to MMINIT.INC.



```

RegionTemplate.slv - WordPad
File Edit View Insert Format Help

$TITLE NOBLE-SOFT ANSWER: CASE <Run>
OPTION LIMROW=0, LIMCOL=0, SOLPRINT=ON, SYSOUT=OFF, ITERLIM=2000000;
OPTION RESLIM=50000, PROFILE=0, SOLVEOPT=REPLACE;
*OPTION LP=XPRESS;
*OPTION MIP=XPRESS;
$OFFLISTING
*SAGE GDY V5
$ONMULTI

* Uncomment if wanting to run MAC-GHG model
*$SET MAC 'YES';

* Uncomment if wanting to use flexible timeslicing
$SET NEWTD 'YES';

$IF NOT '%MODVER%' == 'CMD' $GOTO NOTCMD
$LOG *** Running MARKAL/SAGE V5 ***
$IF NOT '%NEWTD%' == 'YES' $INCLUDE MMINIT.INC
$IF '%NEWTD%' == 'YES' $BATINCLUDE MMINIT.INC REG
$INCLUDE MMINIT.REG
$INCLUDE MMINIT.ANS

For Help, press F1

```

Note that from the user's perspective, after using "Run, Edit GEN File Template" or "Run, Edit Multi-Region GEN File Template" and "Run, Edit Multi-Region SLV File Template" to uncomment the \$SET NEWTD 'YES' line in Template.GEN and RegionTemplate.GEN/SLV, the handling of flexible time slicing by the ANSWER Run Model facility is completely automatic, with no need for the user to intervene at Run Model time.

4.9.9 Other Considerations for Flexible Time Slicing

The ANSWER "smart" spreadsheets, and ANSWER's Import Model Data from Excel, Export Scenario, Import Scenario, Export Scenario Data to Excel, Copy Scenario and Edit Scenario facilities have been reviewed and in some cases enhanced to ensure correct functioning for flexible Time Slicing.

Adding Flexible Time Slice Facilities to an existing database

The "File, Add Flexible Time Slice Facilities" menu function can be used to upgrade a current database to make it Flexible Time Slice aware.

ANSWER "smart" spreadsheets

The ANSWER "smart" spreadsheets from ANSWERver4.xls onwards will function correctly for flexible Time Slicing, *provided that the ANSWER database that is linked to when the smart XLS is opened, was established using AnswerV5.exe version 5.6.1 (or higher) and includes the pre-defined Time Slice structure for the database.*

“File, Import Model Data from Excel” for ANSWER “smart” spreadsheets

The Import Model Data from Excel facility has been enhanced so that when importing from an ANSWER “smart” spreadsheet that employs flexible Time Slicing, TS and TID data parameters involving Time Slices will be correctly imported, *provided that the ANSWER database into which the smart XLS is being imported was established using AnswerV5.exe version 5.6.1 (or higher) and includes the pre-defined Time Slice structure for the database.*

“File, Import Model Data from Excel” for older format ANSWER spreadsheets

The older format ANSWER spreadsheets are those in *** ITEMS ***, *** TS DATA ***, *** TID DATA *** format. The *** ITEMS *** sheets now allow Time Slice Items to be specified, and the Import Model Data from Excel facility has been enhanced so that Time Slice Items on *** ITEMS *** sheets are imported into the database. (To see the format required for Time Slice Items on the *** ITEMS *** sheet, use the “File, Export Scenario Data to Excel” facility to export the BASE scenario for a small database that is flexible Time Slice aware. The Time Slice Items appear at the bottom of the sheet, beneath the Technology Items.)

“File, Export Scenario” facility

This facility has been enhanced so that Time Slice Items (in the BASE scenario) are exported to the IMP file that the Export Scenario facility creates. Of course the Export Scenario facility has always exported TS and TID data parameters involving Time Slices to the IMP file.

“File, Import Scenario” facility

This facility has been enhanced so that Time Slice Items in the IMP file are imported into the database. Of course the Import Scenario facility has always imported into the database TS and TID data parameters involving Time Slices in the IMP file.

“File, Export Scenario to Excel” facility

This facility has been enhanced so that Time Slice Items (in the BASE scenario) are exported to the XLS file that the Export Scenario Data to Excel facility creates. Of course the Export Scenario Data to Excel facility has always exported TS and TID data parameters involving Time Slices to the XLS file that it creates.

Note: Currently the Export Scenario Data to Excel facility exports data *only* in the older *** ITEMS ***, *** TS DATA ***, *** TID DATA *** format.

Copy Scenario facility

This facility has always copied TS and TID data parameters involving Time Slices from the origin scenario to the destination scenario. It appears to be functioning correctly for databases that involve flexible Time Slicing.

Edit Scenario facility

This facility allows the user to edit the Scenario Name (or Description or Comment). Where it is used to edit the Scenario Name, this name change flows through to all TS and TID data parameters, including those that involve Time Slices.

5. Improved Approach for Handling of ADRATIO and Trade in ANSWER

This section describes modifications to ANSWER to allow easier specification and more powerful handling of ADRATIOs and Bilateral Trade. Three additional documents -- *Enhancing ANSWERs Trade Tab to handle Bilateral Trade (7)*, *MARKAL_ANSWER-TD(ZY)+RATRULE-TechFilter (5)* and *ANSWER Load Templates version 5 - Description of Use, inc Bi-Trade Enhancements (1)* -- which are part of the ANSWER/MARKAL release notes accompanying the new version, describe enhancements to the Excel templates and data import facilities to allow specification of these elements in spreadsheets for model upload.

Version 5 of the ANSWER Load Templates allows for the display of Bilateral Trade parameters on TechData sheets, so permitting the user to specify Bilateral Trade between regions of a multi-region model.

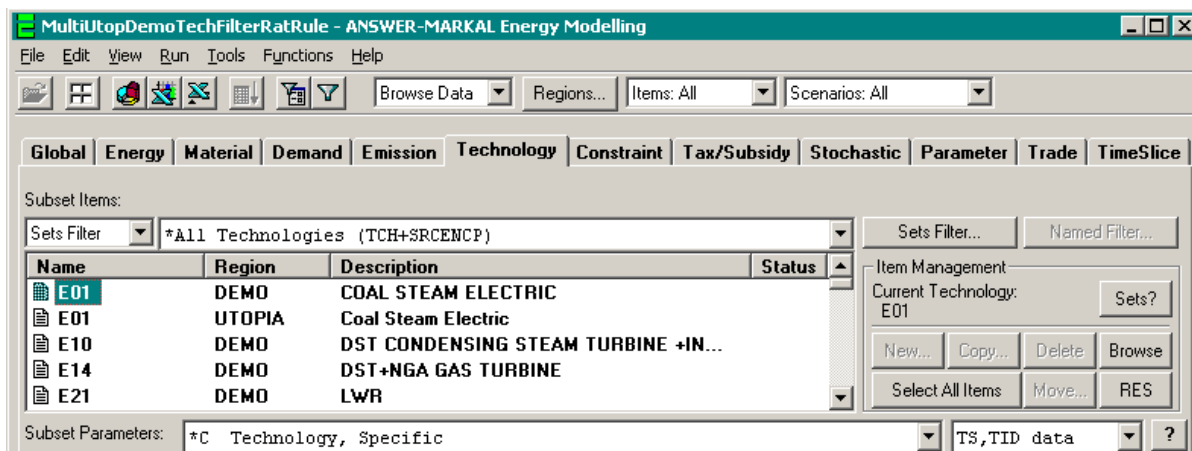
5.1 Technology Items Filters in ANSWER


ANSWER's new Technology Items Filters are powerful filters where any of Technology Name and/or Technology Description and/or Technology Set Membership and/or Input Commodity and/or Output Commodity can form part of the filter. These Filters are defined by the user and stored in the ANSWER database as **Named Filters** (for details see below) and thereafter are available for either or both of the following purposes:



- They can be applied to limit the technologies that are displayed in the Technology Items listview (Subset Item) to those that satisfy the filter rule(s), operating similarly to the filtering by Set Memberships of the Subset Items listview (e.g., to limit the technologies that are displayed to "DMD – Demand Technologies").
- They can be used to simplify the process of defining User Constraints by identifying a group of technologies to which a coefficient is to be applied (e.g., all renewable technologies, where said technologies have a common naming/description convention). For details see chapter 3, "Defining a "Rule-based" Constraint in ANSWER".


The menu option "File, Add Technology Filter and Rule-based Constraints Facilities" can be used to upgrade a current database to make it Technology Filter and Rule-based Constraint aware.

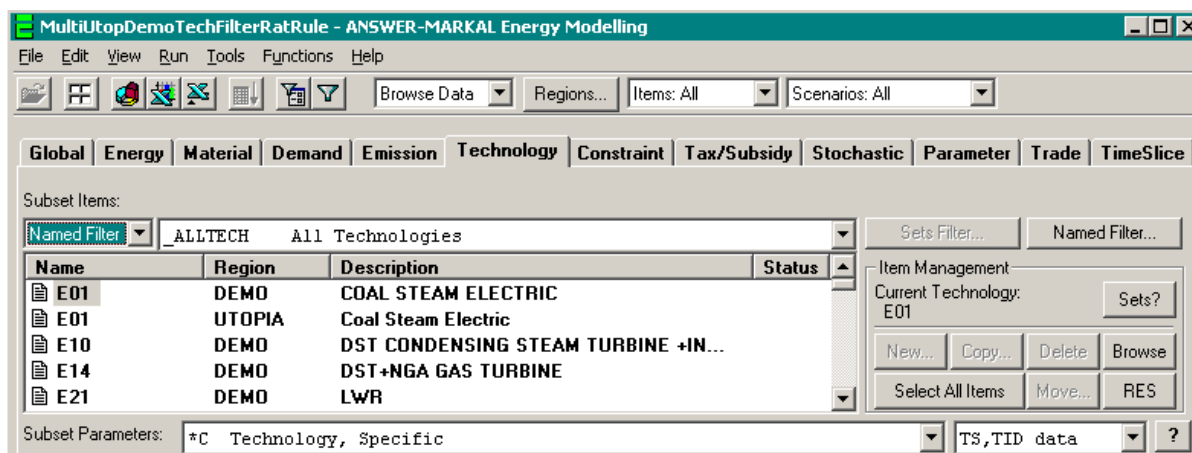
The screen snapshot below shows the changes to the Technology tab to accommodate the needs of the new Technology Items Filters, while also retaining ANSWER's previous filtering by Set Memberships:




Beneath **Subset Items:** and to the left of the customary ***All Technologies (TCH+SRCENCP)** combobox, there is a new combobox that allows the user to choose either a Sets Filter, or a Named Filter (that is a Named Technology Items Filter). The initial setting for this combobox is  with the long combobox presenting ANSWER's standard Set Memberships-based filters.

To the right of the long combobox, there are two buttons:  and . The **[Sets Filter...]** button plays the same role as the **[Specify Items Filter...]** button in previous recent versions of ANSWER, namely it allows the user to invoke a form to specify a Set Memberships Items Filter.

The **[Named Filter...]** button is initially disabled, but becomes enabled when the setting of the combobox beneath **Subset Items:** is changed to , as can be seen in the screen snapshot below:



On the "Named Filter" setting, the long combobox presents the Named Technology Items Filters that are currently defined in the database, the **[Sets Filter...]** button is disabled and the **[Named Filter...]** button is enabled.

Note that an ANSWER database that is Technology Filter aware contains a pre-defined Technology Filter **_ALLTECH All Technologies**, that will be the Named Filter initially selected when the combobox beneath **Subset Items:** is changed to , in an

analogous manner to the selection of ***All Technologies (TCH+SRCENCP)** as the Set Memberships Filter initially selected when the combobox setting is “Sets Filter,” making all technologies initially available.

To define new Named Technology Items Filters, click on the **[Named Filter...]** button to bring up the “Technology Items Filter Management” form:

Name	Description	Modified
_ALLTECH	All Technologies	2006/05/26 18:29
ALL-ELE	Name-based filter defining all electric technologies	2006/05/28 16:42
IND-ALL	All industrial energy use - specified using DMD	2006/05/28 16:58
NAME-CPD	Name Like E6[0-9] + CPD	2006/05/24 10:54
RENEW-ELE	Name- and description-based filter defining all renewable electric technologies	2006/05/28 16:46
TRN-ALL	All transport DMDs	2006/05/21 22:40
TRN-GSL	Filter using DMD, Input and Output Commodity	2006/05/24 13:47

The above form is for a database where as well as the pre-defined Technology Filter **_ALLTECH**, six other Technology Filters have been defined by the user. This form operates in a similar manner to the “Region Management” and “Batch Management” forms, in that it allows new Filters to be created (via **[New...]** or **[Copy...]**) and allows existing Filters to be deleted or edited (via **[Delete]** or **[Edit...]**).

[The **[Delete]** and **[Edit...]** buttons are disabled when the pre-defined Filter **_ALLTECH** is selected, since deletion and editing of this filter are not allowed.]

In addition, clicking on the **[Close & Apply]** button closes this form and results in the selected Technology Filter becoming the currently selected Named Filter in the long combobox, which in turn causes the Technology Items listview to be repopulated with the Technologies that qualify according to the Filter specification.

Clicking on any of the **[New...]** or **[Copy...]** or **[Edit...]** buttons on the “Technology Items Filter Management” form brings up the “Technology Items Filter” form. We now focus on presenting the main details of how the “Technology Items Filter” form operates.

5.1.1 Technology Items Filter Form

The purpose of the new “Technology Items Filter” form is to allow the user to define powerful Technology Item Filters where any of Technology Name and/or Technology Description and/or Technology Set Membership and/or Input/Output Commodity can form part of the filter. These filters are powerful both because they allow any of Name and/or Description and/or Set

Membership and/or Input/Output Commodity to be used as filtering criteria, and also because they provide for union (OR) and negation (NOT) of criteria.

For users who have strict Naming and/or Description conventions within their databases, the Name and/or Description aspects of these filters will prove valuable in filtering down to the desired subset of technologies. Even for users whose databases do not have strict Naming and/or Description conventions, the Set Membership aspects alone will prove valuable, since these filters allow the user to specify Set Membership filters that provide for union (OR) and also for negation (NOT). The capability to filter down to a subset of technologies that have specified Input and/or Output Commodities will provide an enhancement that a number of ANSWER users have suggested as desirable.

The screen snapshot below shows an empty “Technology Items Filter” form.

New Technology Items Filter
Enter Name, Description, Comment and Specify Filter for New Technology Items Filter

Name: _____ Description: _____
Comment: _____

Technologies to be Included:

	Name	Description	Set Memberships	Input Commodity	Output Commodity
Look for:					
or:					
or:					
or:					
or:					

Technologies to be Excluded:

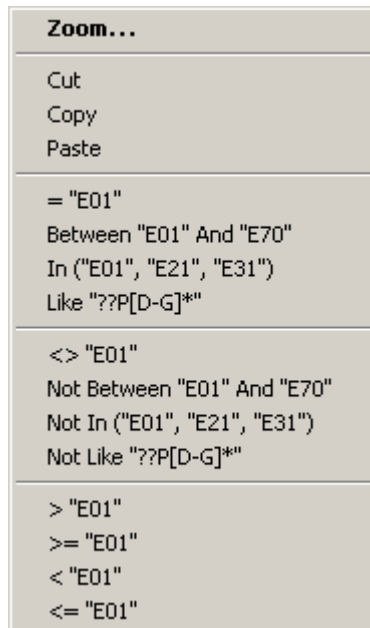
	Name	Description	Set Memberships	Input Commodity	Output Commodity
Look for:					
or:					
or:					
or:					
or:					

Clear Included Clear Excluded OK Cancel

The main features of this form are:

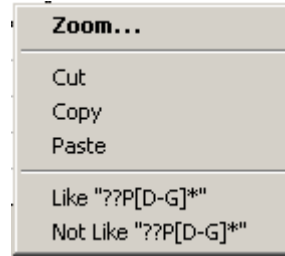
- These are Named filters so the top part of the form allows the user to specify the Name and Description of the Filter. A Comment (optional) may also be specified.
- The top specification area (Technologies to be Included) is where the user specifies – via Name and/or Description masks, and/or Set Membership, and/or Input Commodity and/or Output Commodity masks – filtering criteria for those Technology Items that are to be included in what the filter qualifies.
- The bottom specification area (Technologies to be Excluded) is where the user specifies – via Name and/or Description mask, and/or Set Membership, and/or Input Commodity and/or Output Commodity masks – filtering criteria for those Technology Items that are to be excluded.

- The overall effect of the filter rules in the two specification areas (spreads) is that a single filter is constructed to find Technology Items:
 WHERE {criteria specified in Technologies to be Included spread}
 AND NOT {criteria specified in Technologies to be Excluded spread}
 are satisfied.
- For either specification area, criteria listed for individual cells on the same row are **AND**ed to form a composite row criterion, and then these composite row criteria are **OR**ed.
- The nature of the filtering criteria that may be entered in individual cells of the spreads varies according to whether the cell is in the Name or Description or Set Memberships or Input Commodity or Output Commodity column.
- For a cell in the Name column, the filtering options provided are displayed in the following pop-up menu:

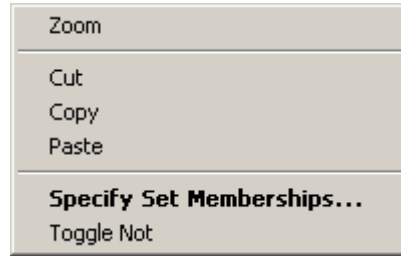


Note that it is not necessary to use the pop-up menu to specify Name filtering criteria – these criteria may simply be typed into the cell. Also, some short cuts are available. For example, if you type **E01** into the cell, on leaving the cell ANSWER will automatically convert to = **“E01”**. And if you type say **E0*** into the cell, on leaving the cell ANSWER will automatically convert to **Like “E0*”**.

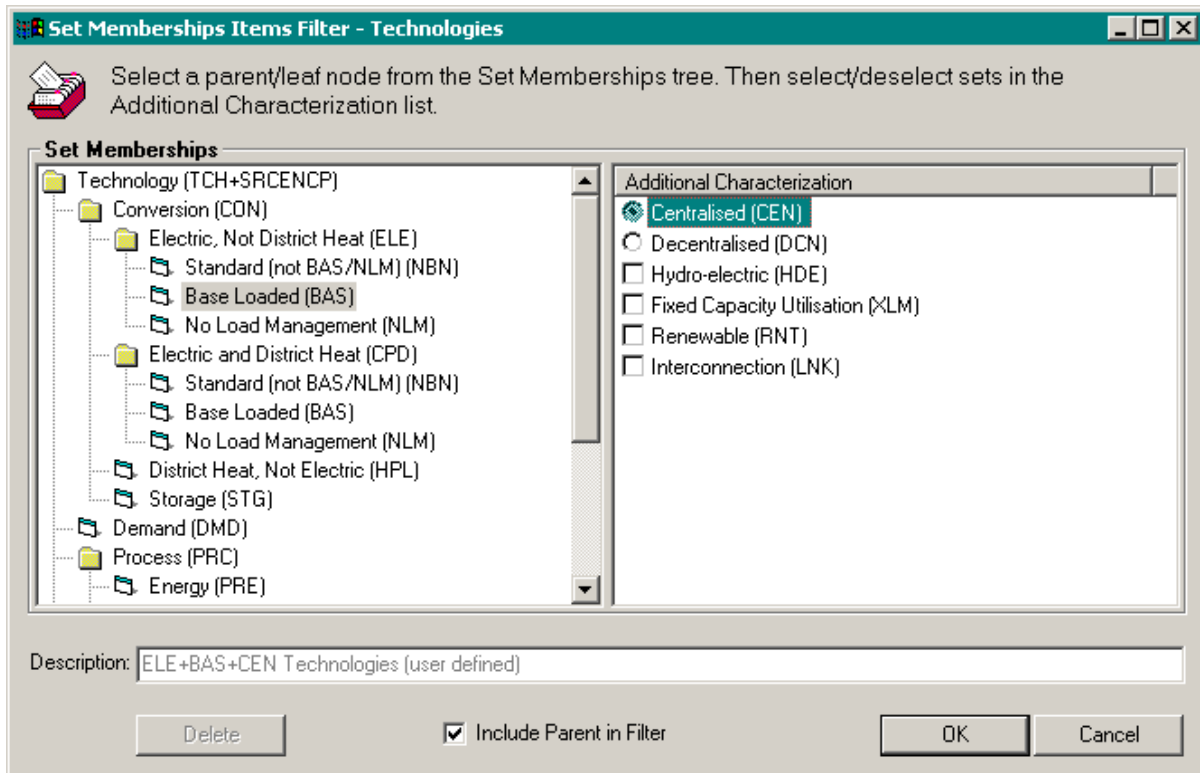
- For a cell in the Description column, only two of the above filtering options are provided: **Like** and **Not Like**. So to specify that the Description contains say “renewable” the user would specify the Description filtering criteria as **Like “*renewable*”**.



- For a cell that is in the Set Memberships column, the following right-mouse pop-up menu option is provided:



Invoking the **Specify Set Memberships...** option allows the user to bring up the “Set Memberships Items Filter - Technologies” form that is shown below, in which the user has specified Set Membership criteria of ELE+BAS+CEN; that is, the filtering criteria is to restrict to those technologies that are in SET ELE and SET BAS and SET CEN.



- The Set Membership filtering criteria specified above will be displayed in the Technologies to be Included specification area as follows:

Technologies to be Included:				
	Name	Description	Set Memberships	Input Commodity
Look for:			ELE+BAS+CEN	
or:				

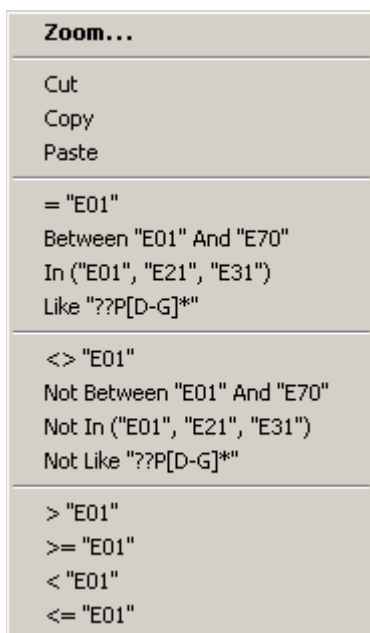
Note that it is not necessary to use the **Specify Set Memberships...** menu option to specify Set Membership filtering criteria – these criteria may simply be typed into the cell. For example, you could simply type **ELE+BAS+CEN** into the cell. On leaving the cell ANSWER will automatically check that the Sets that you have entered are valid MARKAL Sets.

- The right-mouse pop-up menu option “Toggle Not” allows the user to toggle the sense of the Set Membership criteria. Applying this menu option to the above cell would result in the following:

Technologies to be Included:				
	Name	Description	Set Memberships	Input Commodity
Look for:			Not ELE+BAS+CEN	
or:				

Applying the “Toggle Not” menu option again would remove the “Not ”, so “Not ELE+BAS+CEN” would revert to “ELE+BAS+CEN”.

- For a cell in the Input Commodity (or Output Commodity) column, the filtering options provided are based on the **Name** of the Input/Output Commodity. The same range of filtering options is provided in respect of the Commodity Name as are provided for Technology Name. These are displayed (again) in the following pop-up menu:



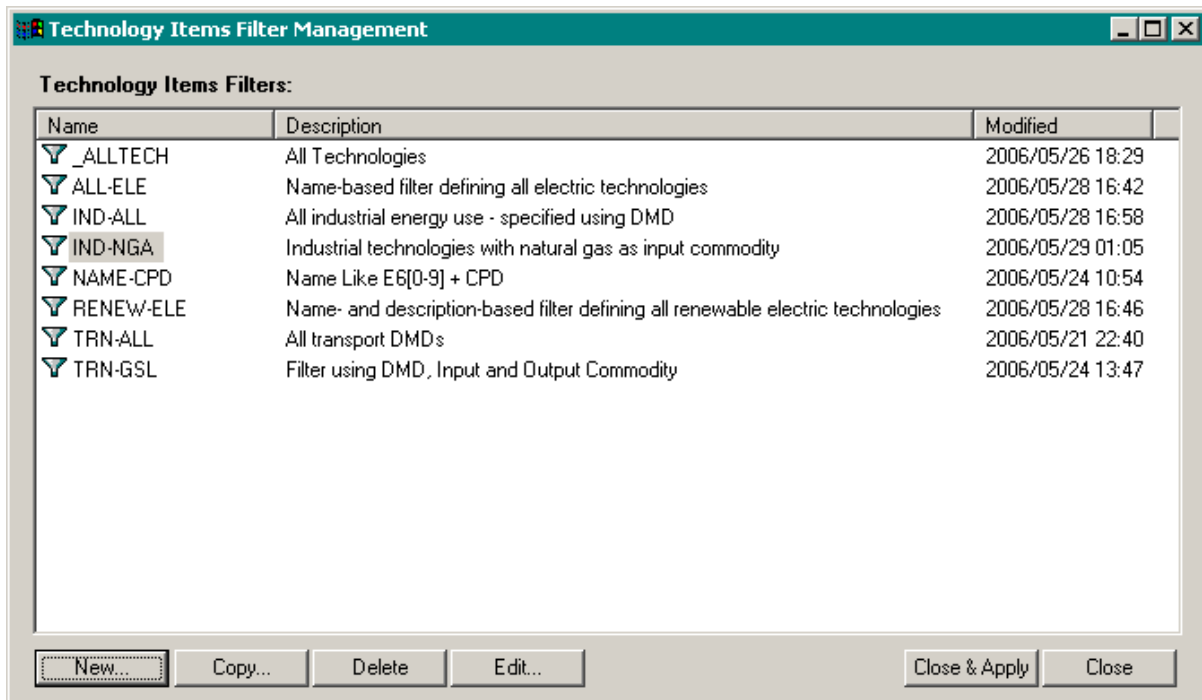
- Suppose for example that a user wants to specify a filter to select technologies that have coal (COA) as an Input Commodity and electricity as an Output Commodity, where there are several different electric commodities whose names all match “*ELC”. Then the user would specify Input and Output Commodity criteria as follows:

Technologies to be Included:					
	Name	Description	Set Memberships	Input Commodity	Output Commodity
Look for:				= "COA"	Like "ELC"
or:					

- Note that in both the Technologies to be Included and Excluded specification areas (spreads), the filtering options that are available for all cells include **negation** options (e.g. Not Between, Not In, Not Like for Name cells; Not Like for Description cells; Not for Set Membership cells; ...). In particular this affords the user the additional flexibility of being able to specify negation options within the Technologies to be Included spread, if that is more convenient or appropriate than placing the positive option (Between, In, Like) within the Technologies to be Excluded spread.

The screen snapshot below shows a completed “Technology Items Filter” form that specifies a Filter to select all Industrial demand devices that have natural gas as an Input Commodity.

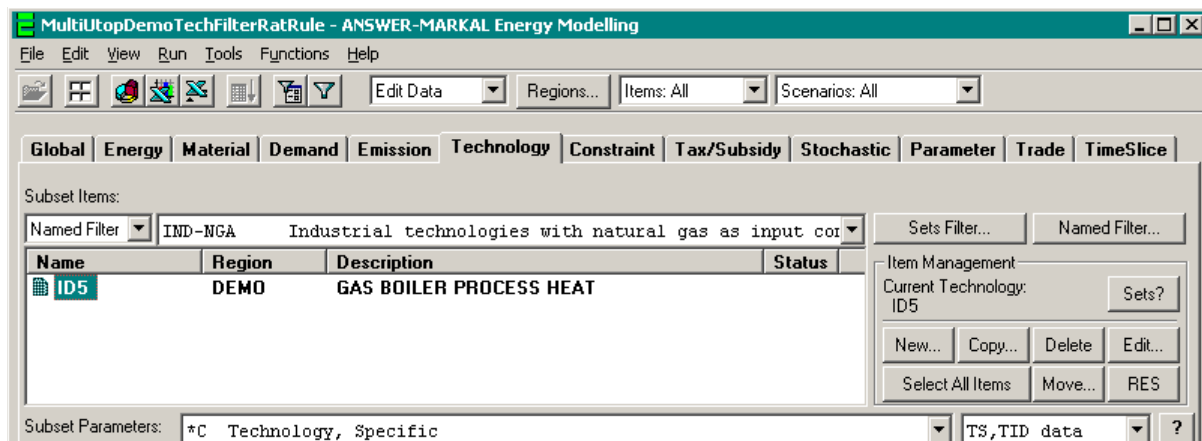
Clicking on the [OK] button saves this Filter to the database and returns us to the “Technology Items Filter Management” form:



We may now create further new Technology Filters, or copy, delete or edit existing Technology Filters.

If we simply click on [**Close**] to close the form and return to the Technology tab display, the long combobox will be re-populated with the Technology Items Filters displayed above. In particular, the newly created Filter IND-NGA will now be available for sub-setting the Technology Items listview whenever needed. It may also be used when constructing Rule-based User Constraints, as discussed in Section 3.

If we click on the [**Close & Apply**] button with IND-NGA as the selected Technology Filter, this closes the form and results in IND-NGA becoming the currently selected Named Filter in the long combobox, which in turn causes the Technology Items listview to be repopulated with the qualifying Technologies for the Filter, in this case just a single Technology ID5, as displayed below:



5.1.2 Guidelines for Specifying Technology Items Filters

The Technology Items Filter form allows the specification of quite complex filters. In general the user is encouraged to specify filters in the fashion that is most “natural” to them. But some specifications are more time-consuming to execute than others, whether this execution is related to applying a Technology Filter to subset items on the Technology tab, or to resolving a rule-based Constraint (either on the Constraint tab, or when carrying out a model run – see Chapter 3.0 below).

When specifying a Technology Items Filter, and particularly if working with a large multi-region database, the user is encouraged to keep the following guidelines in mind if responsiveness becomes an issue:

1. The most efficient filter to execute is a single row filter that involves only Name and/or Description and/or Set Memberships criteria, and that does not involve any Input Commodity or Output Commodity criteria, nor involve any Technologies to be Excluded criteria. This efficiency is little affected if the filter involves multiple rows but where *every* such row involves only Name/Description/Set Memberships criteria, and does not involve any Input/Output Commodity criteria.
2. Where the Technologies to be Excluded part of a filter involves simple Name/Description/Set Memberships criteria, efficiency should be little affected unless this part of the filter generates a large number of Technologies to be excluded.
 - Nonetheless, efficiency will be enhanced if use of the Technologies to be Excluded spread can be avoided altogether. Thus the user who wishes to specify the most efficient filter that selects all industrial technologies should specify Name criteria **Like “I*”** and Set Memberships criteria **DMD** in the (same row of the) Technologies to be Included spread, rather than specify Name criteria **Like “I*”** in the Technologies to be Included spread, and Name criteria **Like “IMP*”** in the Technologies to be Excluded spread (to exclude Import Technologies).
3. The least efficient filter to execute is one that involves multiple rows in both the Technologies to be Included and Excluded spreads, and where there are rows in *each* of the following three categories:
 - Input Commodity but no Output Commodity criteria;
 - Output Commodity but no Input Commodity criteria, and
 - Input Commodity and Output Commodity criteria.
4. In view of 3, when specifying a multi-row filter that involves Input and/or Output Commodity criteria, if possible try to ensure that *every* row of the filter falls into just *one* of the following three categories:
 - Input Commodity but no Output Commodity criteria;
 - Output Commodity but no Input Commodity criteria, or
 - Input Commodity and Output Commodity criteria.

So for example a multi-row filter in which *every* row of the filter involves say Input and Output Commodity criteria (and possibly also Name/Description/Set Memberships criteria) will execute more efficiently than a filter in which some rows involve say Input but no Output Commodity criteria, and other rows involve say Output but no Input Commodity criteria.

5. A filter that involves just Input Commodity criteria, or just Output Commodity criteria, will execute more efficiently than a filter that involves both Input Commodity criteria and Output Commodity criteria.
6. If possible, try to avoid use of the **Not In (...)** construct, particularly if there are more than a few Technologies (Input/Output Commodities) specified in the list inside the parentheses (). The Microsoft Access query language does not handle the **Not In (...)** construct anywhere near as efficiently as constructs such as **Not Like**.

5.1.3 Exporting and Importing a Database's Technology Items Filters

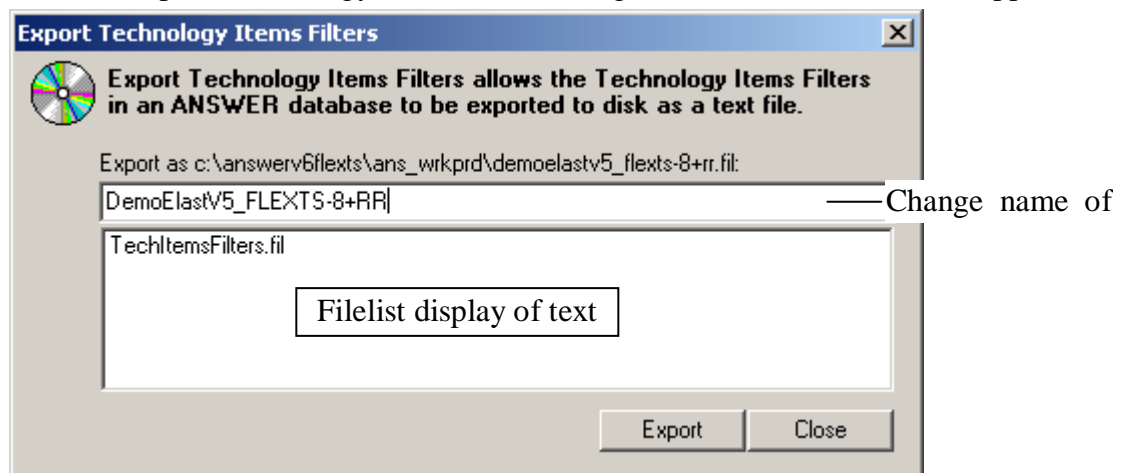
ANSWER incorporates two facilities which together enable copying of a Database's Technology Items Filter from one Database to another. The origin Database and the target Database may or may not be on the same computer. To copy a Database's Technology Items Filters from one Database to another requires two stages:

- Exporting the Technology Items Filters from the origin Database into the Answer Work folder (default C:\AnswerV5\Ans_WrkPRD) as a text file; and
- Importing the Technology Items Filters from the text file in the Answer Work folder into the target Database.

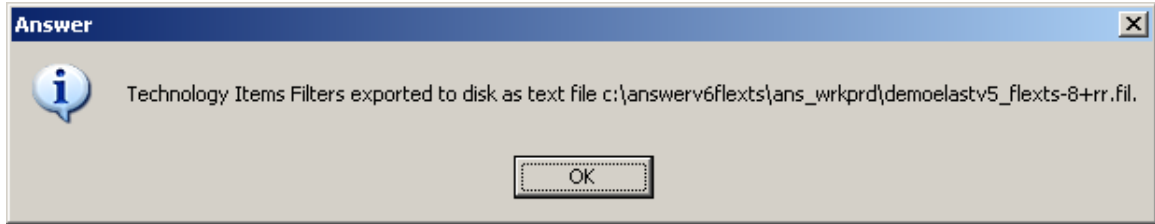
5.1.3.1 Exporting a Database's Technology Items Filters

To export a Database's Technology Items Filters:

1. Open the origin Database.
2. Click on **File** in the menu bar and choose **Export** then choose **Technology Items Filters...** in the drop menu.
3. An Export Technology Items Filters dialogue box (shown below) will appear.



4. The name given to the Technology Items Filters file defaults to the Database name, and always has a file type of '.fil'. To vary the name given to the Technology Items Filters file, either change the name in the 'Export as c:\answerv5\ans_wrkprd\.fil:' text box, or choose an existing name from the file list display.
5. Click on the **[OK]** button and a message box will appear to advise that the Technology Items Filters information for the origin Database has been exported to C:\AnswerV5\Ans_WrkPRD as text file <name>.fil:

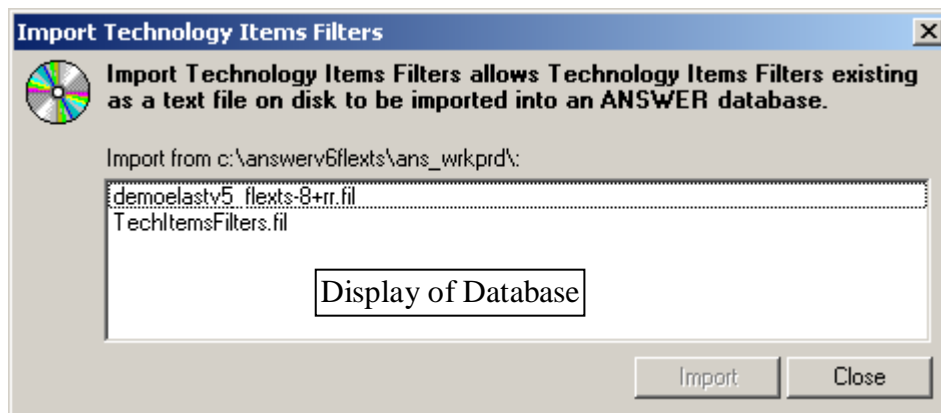


5.1.3.2 Importing a Database's Technology Items Filters

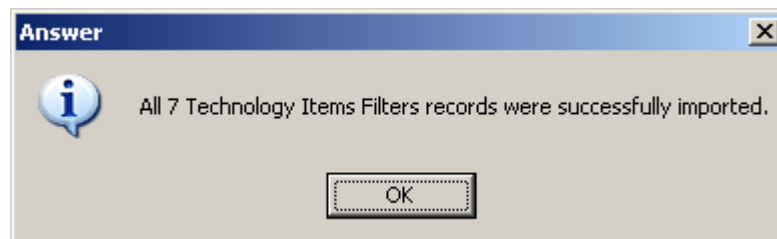
If the Technology Items Filters information in text file <name>.fil is to be copied to a Database on a separate computer, the user will need to copy/move the file to the C:\AnswerV5\Ans_WrkPRD folder in the target computer.

To import a Database's Technology Items Filters:

1. Open the target Database.
2. Click on **File** in the menu bar and choose **Import** then choose **Technology Items Filters...** in the drop menu.
3. An Import Technology Items Filters dialogue box (shown below) will appear, in which all the Technology Items Filters text files (*.fil) produced by previous Export Technology Items Filters operations and held in the C:\AnswerV5\Ans_WrkPRD folder will be displayed.



4. Click on the required Technology Items Filters file <name>.fil in the filelist display.
5. Click on the [OK] button. The following message will appear to advise that the Technology Items Filters records have been successfully imported:



Note that if a named Technology Items Filter already exists in the target database it is replaced by the specification in the Import .fil file.

5.2 Defining a “Rule-based” Constraint in ANSWER

5.2.1 Preliminaries

You need to be running ANSWER version 5.6.1 or higher, and to make your ANSWER database aware of “rule-based” constraints. To make an existing ANSWER database aware of Rule-Based Constraints and of the Technology Filters on which Rule-Based Constraints depend, open the database with ANSWER version 5.6.1 or higher, and invoke “File, Add Technology Filter and Rule-based Constraint Facilities” from the menu bar. (You must invoke immediately after opening the database, if you move to the Data/Results screen, this menu item becomes disabled, and you will need to close the database and then reopen it in order for the menu item to be available.)

5.2.2 An example: A rule-based Constraint – renewable electricity production

For ease of explanation, we demonstrate what you would need to do to create a rule-based Constraint requiring renewable electricity production to be at least 5% of total electricity production. That is:

$$1.0 * \{\text{renewable electricity production}\} - 0.05 * \{\text{total electricity production}\} \geq 0$$

Previously when specifying this constraint in ANSWER as a user-defined constraint the coefficients had to be “normalized” since the renewable electricity producers are included in the overall set of producers, and the equation written in the form:

$$0.95 * \{\text{renewable electricity production}\} - 0.05 * \{\text{non-renewable electricity production}\} \geq 0$$

For rule-based Constraints, ANSWER will handle this for the user, and just the first more natural form of the equation needs to be provided by the user. This makes it much easier to adjust this constraint by simply changing the 0.05 in this case.

The overview of what you need to do to create such a constraint using the new rule-based facility is:

- A. Create a (named) Technology Items Filter (rule) that selects renewable electric technologies.
- B. Create a (named) Technology Items Filter (rule) that selects all electric technologies.
- C. Use the Constraint tab to define a rule-based Constraint that relies on the Technology Filters that you have created at steps A and B.

This example is fleshed out in the next section.

5.2.3 Technology Items Filters to Select Renewable/All Electric Technologies

For details regarding ANSWER’s new Technology Items Filters and how to invoke the “Technology Items Filter” form see sections 2.1 to 2.3 above.

In the section below “Using the Constraint tab to define a Rule-based User Constraint”, it is assumed that the Technology Items Filter that selects renewable electric technologies is named RENEW-ELE, and that the Technology Items Filter that selects all electric technologies is named ALL-ELE. We now indicate how the user might define these two Technology Items Filters.

We assume that user-imposed naming conventions mean that the Names of all technologies that produce electricity begin with “E” and that no other technology Names begin with “E”, provided that we exclude export technologies whose names begin with “EXP”. We also assume that all renewable technologies, and only renewable technologies, have “renew” somewhere within their Descriptions.

Then to define the ALL-ELE filter, invoke the Technology Items Filter form, specify the Name and Description of the filter, and then enter the Name criteria **Like “E*”** in the Technologies to be Included spread and enter the Name criteria **Like “EXP*”** in the Technologies to be Excluded spread, as follows:

New Technology Items Filter
Enter Name, Description, Comment and Specify Filter for New Technology Items Filter

Name: ALL-ELE Description: Name-based filter defining all electric technologies

Comment:

Technologies to be Included:

	Name	Description	Set Memberships	Input Commodity	Output Commodity
Look for:	Like "E*"				
or:					
or:					
or:					
or:					
or:					

Technologies to be Excluded:

	Name	Description	Set Memberships	Input Commodity	Output Commodity
Look for:	Like "EXP*"				
or:					
or:					
or:					
or:					
or:					

Clear Included Clear Excluded OK Cancel

When it is invoked the ALL-ELE filter will select Technologies whose Names are **Like “E*”** but whose Names are not **Like “EXP*”**, that is Technologies whose Names begin with “E” but do not begin with “EXP”. Given the naming conventions assumed, this filter selects all electric technologies. [Note that other filters could be constructed, such as all members of set CON with ‘ELC’ as an Output Commodity.]

To define the RENEW-ELE filter, invoke the Technology Items Filter form and enter both the Name criteria **Like “E*”** and the Description criteria **Like “*renew*”** in the top row of the Technologies to be Included spread (and specify the Name and Description of the filter itself), as follows:

New Technology Items Filter

Enter Name, Description, Comment and Specify Filter for New Technology Items Filter

Name: Description:

Comment:

Technologies to be Included:

	Name	Description	Set Memberships	Input Commodity	Output Commodity
Look for:	Like "E*"	Like "*renew*"			
or:					
or:					
or:					
or:					
or:					

Technologies to be Excluded:

	Name	Description	Set Memberships	Input Commodity	Output Commodity
Look for:					
or:					
or:					
or:					
or:					
or:					

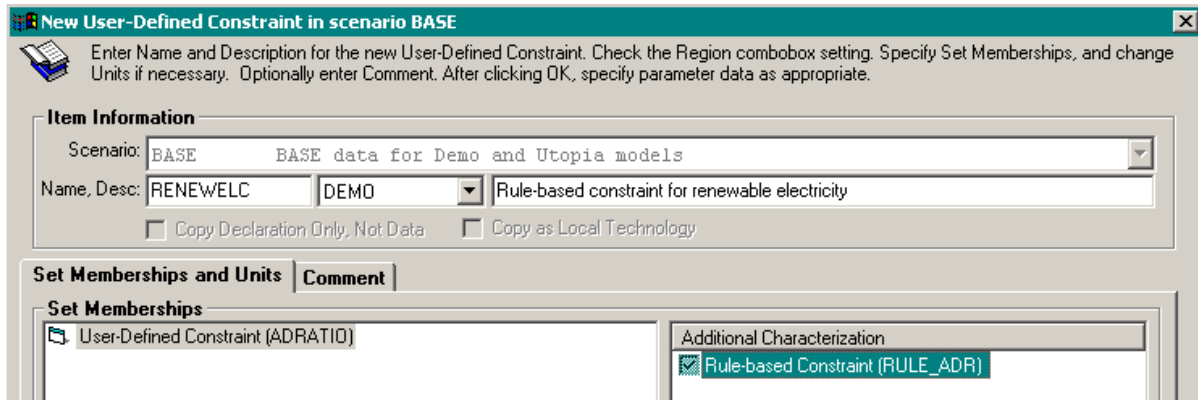
When it is invoked the RENEW-ELE filter will select Technologies that satisfy the composite row criteria of having Names **Like "E*"** and Descriptions **Like "*renew*"**, that is Technologies whose Names begin with "E" and that have "renew" somewhere within their Descriptions. Given the naming conventions assumed, this filter selects all renewable electric technologies.

5.2.4 Using the Constraint tab to define a Rule-based User Constraint

1. Click on the button in the Item Management frame to bring up the New User-Defined Constraint form.

2a. Specify Name, Region and Description for the Constraint. For this example, we specify Name = "RENEWELC", Region = "DEMO", Description = "Rule-based constraint for renewable electricity"

Note that there is a new checkbox under Additional Characterization on the RHS of the Set Memberships frame:



2b. Check this checkbox to indicate that you wish this to be a rule-based constraint.

2c. Click on the  button.

3. As is the case with a standard User-Defined Constraint, ANSWER automatically creates an instance of the RAT__RHS parameter, with the entry in the Bound column containing the placeholder **-none-**:

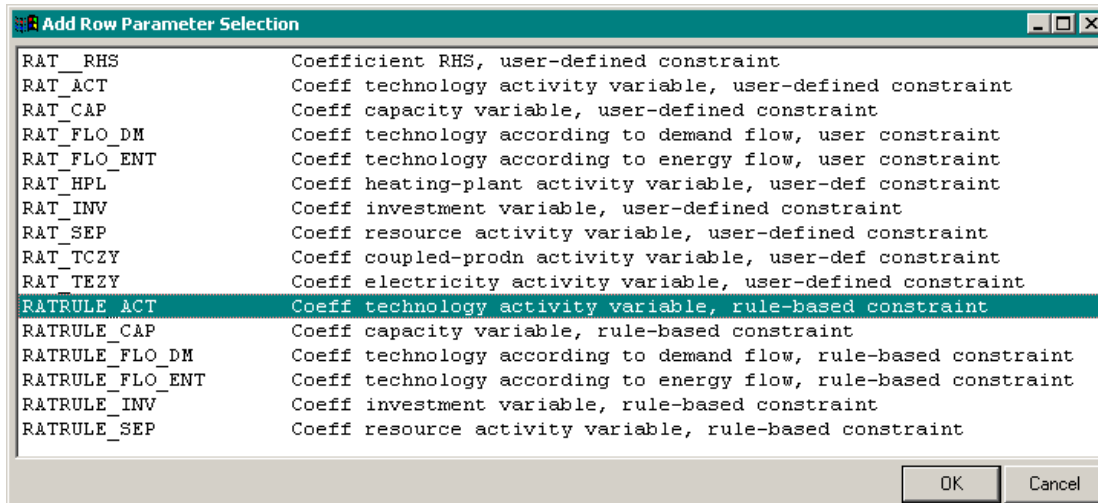
Scenario	Parameter	Region	Tech/Filter	Constraint	Item3	TimeSlic	1990	2000	
?	BASE	RAT__RHS	?	DEMO	-	RENEWELC	-none-	-	
Add	BASE		?						

Use the direct-cell edit facility to change the **-none-** to whichever of **LO/FX/UP** is appropriate according to the sense of the constraint (\geq , $=$, \leq respectively) and specify appropriate numeric values.

For this example, we replace **-none-** by **LO**, since the sense of the constraint is \geq , and we specify zeros in each time period, as follows:

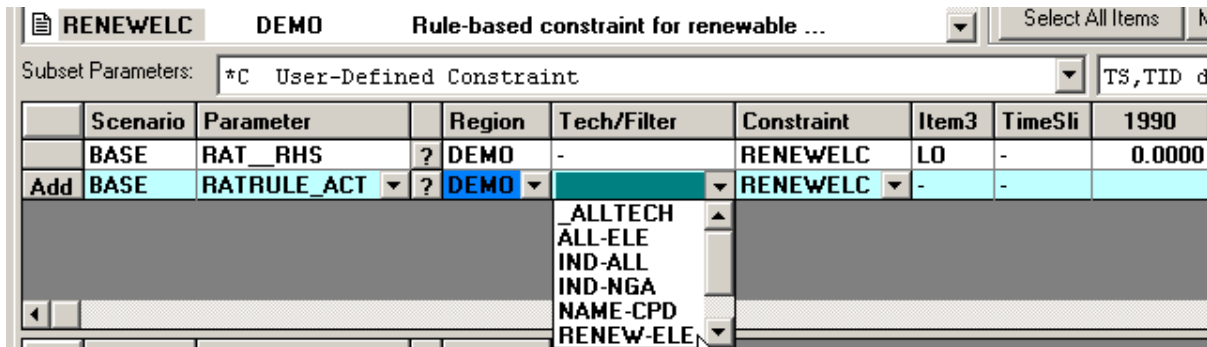
Scenario	Parameter	Region	Tech/Filter	Constraint	Item3	TimeSlic	1990	2000	2010		
	BASE	RAT__RHS	?	DEMO	-	RENEWELC	LO	-	0.0000	0.0000	0.0000
Add	BASE		?								

4. Use the Parameter combobox in the AddRow to select the appropriate parameter. This can be done either by dropping down the combobox and using the scroll bar to display the parameters of interest, or more conveniently by right-mouse clicking on the AddRow Parameter combobox and selecting "View Descriptions" which displays all the available rule-based constraint parameters and their descriptions, as follows:



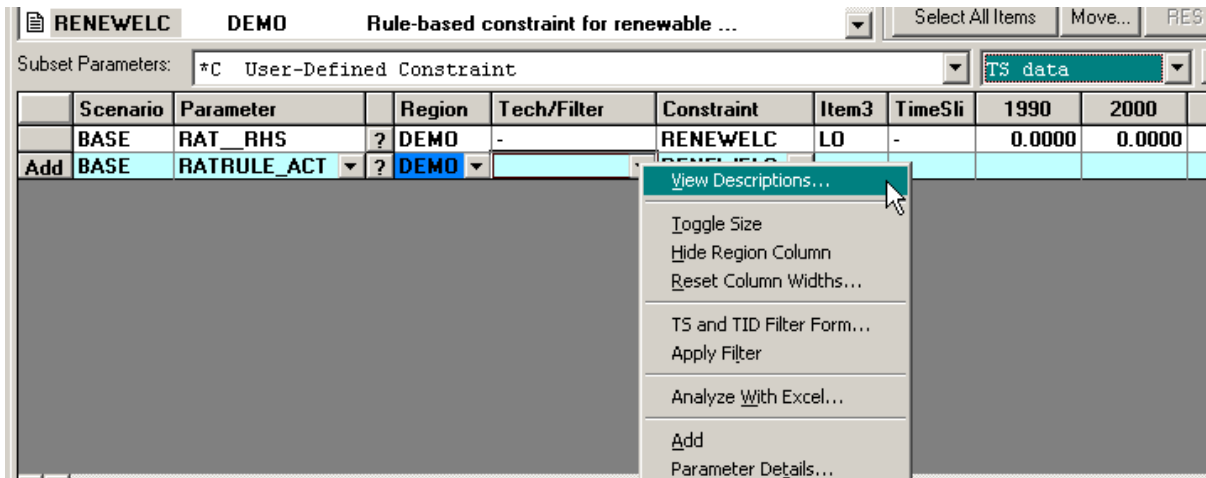
Note that for a rule-based Constraint, and only for a rule-based Constraint, six new “RATRULE_*” parameters (RATRULE_ACT, RATRULE_CAP, RATRULE_FLO_DM, RATRULE_FLO_ENT, RATRULE_INV and RATRULE_SEP) are available, *in addition to the standard RAT_* parameters (RAT_ACT, RAT_CAP etc) that are available for all Constraints.*

For this example we select **RATRULE_ACT**. Drop-down the Tech/Filter combobox in the AddRow, and select the appropriate (named) Technology Filter from the list of Technology Filters that is displayed:

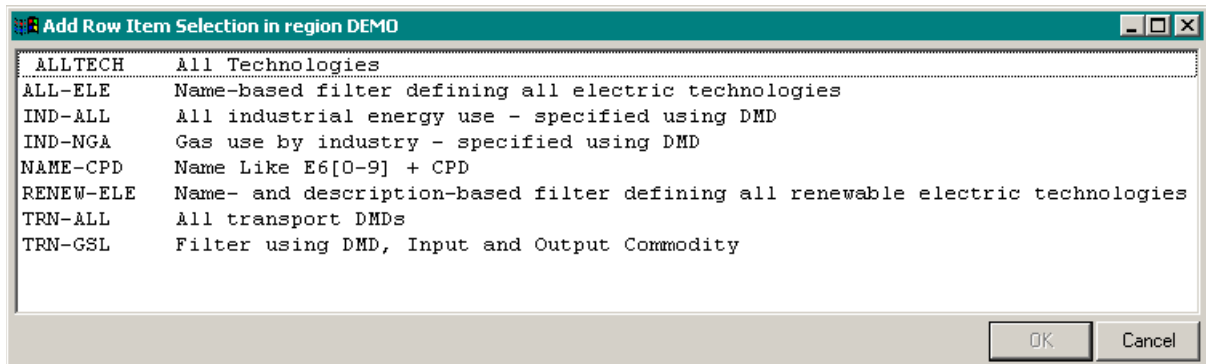


For this example, we select **RENEW-ELE**.

Alternatively, right-mouse click on the Tech/Filter combobox and select “View Descriptions”:

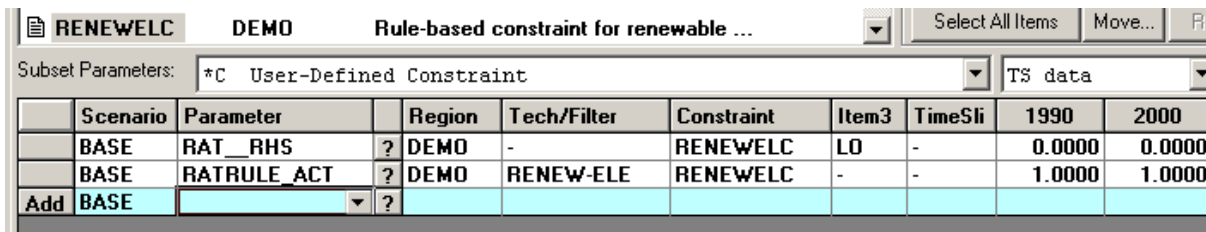


This brings up the following form that has the benefit of displaying both the Name and the Description for each available Technology Filter:



Select the appropriate Technology Filter from this form, in this case RENEW-ELE, and click on the [OK] button.

6. Specify appropriate numeric values (for this example we specify **1.0** in each time period) for the renewable electric producers and press the ↓ key or hit the Add button to add the completed row into the TS spread, as follows:




7. Repeat steps 4, 5, 6 to specify additional RATRULE_* rows as necessary to complete the Constraint.

To complete this example, we again select parameter **RATRULE_ACT** at step 4, but at step 5 select Technology Filter **ALL-ELE**, and at step 6 specify **-0.05** in each time period and then click on the ↓ key to add the row into the TS spread, as follows:

Scenario	Parameter	Region	Tech/Filter	Constraint	Item3	TimeSli	1990	2000	
BASE	RAT_RHS	?	DEMO	-	RENEWELC	LO	-	0.0000	0.0000
BASE	RATRULE_ACT	?	DEMO	ALL-ELE	RENEWELC	-	-	-0.0500	-0.0500
BASE	RATRULE_ACT	?	DEMO	RENEW-ELE	RENEWELC	-	-	1.0000	1.0000
Add	BASE								

[The RATRULE_ACT row involving ALL-ELE appears above the row involving RENEW-ELE, even though added after it, because ANSWER sorts by Parameter, then Region, then Tech/Filter.]

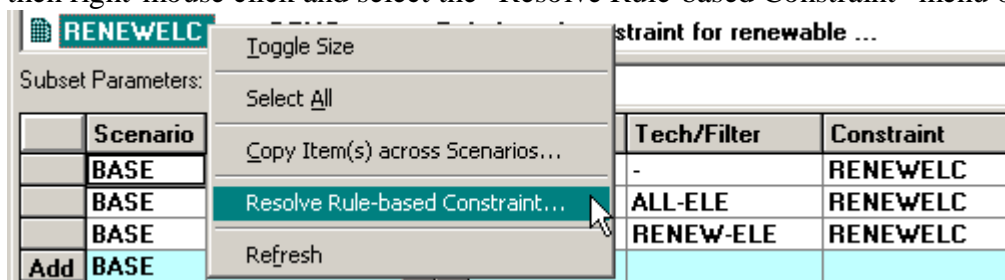
5.2.5 Change of Set Memberships on the Constraint tab

- The user may change the Set Memberships of a Constraint from standard to rule-based, or vice-versa, by clicking on the  button in the Item Management frame to bring up the Edit User-Defined Constraint form, and then by checking/unchecking the Rule-based checkbox to change from standard to rule-based, or vice-versa, respectively.
- If the user changes the Set Memberships of a Constraint from standard to rule-based, then all of the RAT_* parameters associated with the Constraint will be retained unchanged.
 - And after the change, the RATRULE_* parameters will now also be available for selection in the AddRow Parameter combobox.
- If the user changes the Set Memberships of a Constraint from rule-based to standard, then after asking the user to confirm change of Set Memberships, the RAT__RHS parameter and any RAT_* parameters that may be associated with the Constraint will be retained unchanged.
 - But ANSWER will automatically delete existing RATRULE_* parameters associated with the Constraint, and these parameters will no longer be available for selection in the AddRow Parameter combobox.

5.2.6 Displaying how a Rule-based Constraint will be resolved at Run Model time

As mentioned previously, an added benefit of the Rule-based Constraints is that they are resolved at run time to ensure that all technologies found in the various scenarios involved in the run are considered dynamically as candidates for the constraint. This is discussed further below, but ANSWER also provides a facility to enable the user to preview how the rule-based constraint will be resolved, as discussed here.

- To display how a rule-based Constraint will be resolved at Run Model time (that is, to display each individual row of the Constraint with the fully resolved coefficients as they will be generated at Run Model time) select the rule-based Constraint in the Items listview, then right-mouse click and select the “Resolve Rule-based Constraint” menu option:



2. The “Resolve Rule-based Constraint” form will appear. Initially the form is populated with a specially constructed temporary Case named `_SELSCEN` that comprises the BASE scenario, followed by the non-BASE scenarios in the Home screen Selected Scenarios listview in alphabetical order of CaseName. (Only the upper part of the form is displayed in the screen snapshot below). Often resolving the Constraint against the `_SELSCEN` temporary Case will be sufficient for the user to determine whether the Constraint has been correctly specified. See 3. below for details of how to resolve the Constraint against an *online* Case.

The spread displays how the Rule-based Constraint will be resolved at Run Model time for Case:

Scenario	Parameter	Region	Technology	Constraint	Bnd/Ener	TimeSlice	1990	2000	2010

3. To resolve the Constraint against an *online* Case, click on the **[Select Case...]** button to bring up a “Case Selection” form that displays all online Cases involving the region for which the rule-based Constraint is specified (in this case DEMO). This display will include Cases for which the results have been removed with just the Case definition remaining, and as can be seen also includes the temporary Case `_SELSCEN`:

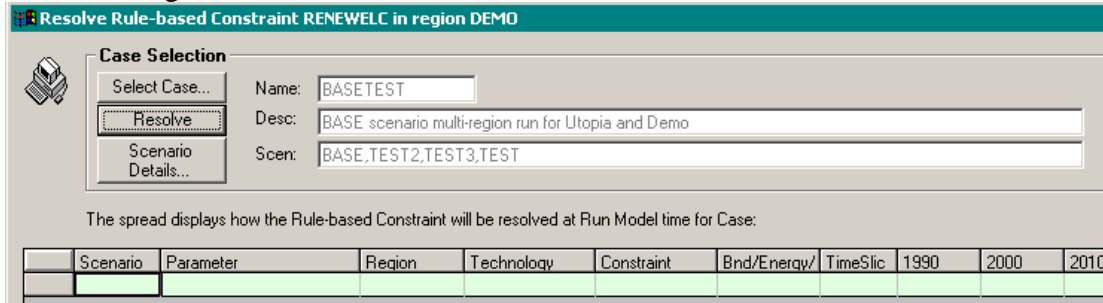
Name	Description	Created
_SELSCEN	Temporary Case comprising selected scenarios, ...	2004/05/18 21:44
BASEBOTH	BASE scenario multi-region run for Utopia and D...	2006/04/19 18:01
BASEDEM2	BASE scenario run for Demo only to 2020	2006/04/29 21:22
BASEDEM3	BASE scenario run for Demo only to 2020 - GAM...	2004/02/06 16:04
BASEDEMO	BASE scenario run for Demo only to 2020	2006/04/19 12:48
BASETEST	BASE scenario multi-region run for Utopia and D...	2006/02/20 23:33

Select the Case of interest and click on the **[OK]** button.

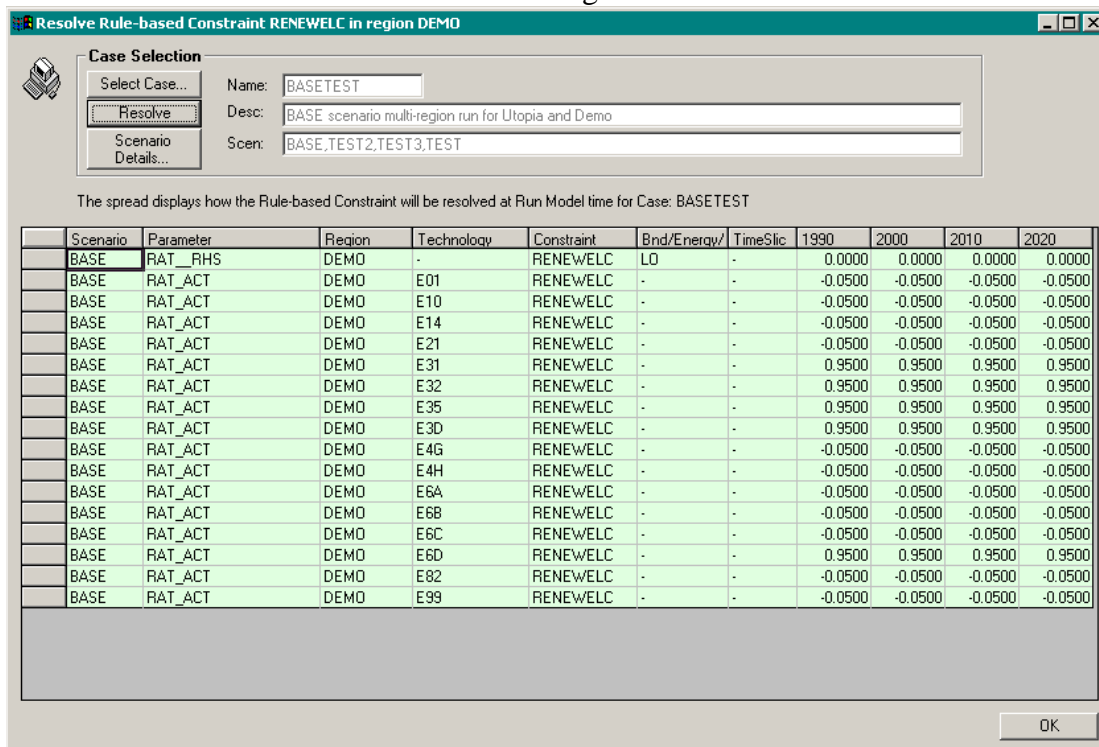
[If necessary the user can create a Case of interest by exiting this form and the “Resolve Rule-based Constraint” form, moving to the Home screen, bringing up the Run Model form and specifying the ordered scenarios to be used, and then submitting with the “Generate Files, Do Not Run” checkbox checked.]

The Case Selection form has been enhanced by the addition of a **[Scenario Details...]** button, allowing the user to display details of the scenarios comprising the selected Case.

- The “Resolve Rule-based Constraint” form will now appear as follows, with the Name and Desc. textboxes containing the Name and Description respectively for the selected Case, and with the Scen. textbox containing a list of the Scenarios that comprise the selected Case in Run Model scenario order. The **[Resolve]** button has the focus pending the user clicking on it to resolve the Constraint.




- Click on the **[Resolve]** button to resolve the Constraint. The spread displays each individual row of the Constraint that will be generated at Run Model time for the scenarios involved with the selected Case BASETEST. Note that there are a number of technologies in the spread (E31, E32, E35, E3D, E6D) for which the RAT_ACT coefficients are 0.95: these are the renewable electric technologies in the DEMO database. They pick-up the value 0.95 because they qualify for both the **ALL-ELE** and **RENEW-ELE** rules so $+1 - 0.05 = 0.95$ is calculated by ANSWER as the appropriate final coefficient for RAT_ACT. The remaining technologies in the spread for which the RAT_ACT coefficients are -0.05 are the non-renewable electric technologies.



- If any of the Technology Items Filters used in defining a rule-based Constraint involve Technologies whose Set Memberships are incompatible for the RAT_* parameter with which they are associated, then the rows that correspond to these Technologies are put out

to the spread colored pink, and a message box alerts the user. Note that these rows are not put out to the RULES .DDS at Run Model time. (To do so would lead to GAMS \$170 compilation errors.) For example if the definition of filter ALL-ELE had not excluded export Technologies, whose names begin with “EXP”, then there would be a pink row in the spread for each export Technology, since such Technologies’ Set Memberships are incompatible for the RAT_ACT parameter.

BASE	RAT_ACT	DEMO	E3D	RENEWELC	-	-	0.9500	0.9500	0.9500	0.9500
BASE	RAT_ACT	DFMD	F4G	RNFWF1C	-	-	-0.0500	-0.0500	-0.0500	-0.0500
BASE	RAT_ACT	Some Technology Set Memberships incompatible with RAT_* Parameter								-0.0500
BASE	RAT_ACT	 Some of the Technology Items Filters used in this Rule-based Constraint generate Technologies whose Set Memberships are incompatible with those required for the RAT_* parameter with which they are associated.								-0.0500
BASE	RAT_ACT	In the spread, there are 3 rows (colored pink) that correspond to such Technologies, and that will NOT be put out at Run Model time.								-0.0500
BASE	RAT_ACT	You may wish to check the definition of the Technology Items Filters used.								-0.0500
BASE	RAT_ACT	OK								-0.0500
BASE	RAT_ACT	DEMO	EXPCOAC	RENEWELC	-	-	-0.0500	-0.0500	-0.0500	-0.0500
BASE	RAT_ACT	DEMO	EXPELC1	RENEWELC	-	-	-0.0500	-0.0500	-0.0500	-0.0500
BASE	RAT_ACT	DEMO	EXRJTF1	RENEWELC	-	-	-0.0500	-0.0500	-0.0500	-0.0500

- For additional details regarding how rule-based Constraints are resolved at Run Model time, see the following section “Run Model Considerations for Rule-based Constraints”.
- The [Scenario Details...] button on the form allows the user to display details of the scenarios comprising the selected Case. The only purpose of this button is to provide these extra details in case they may be useful in verifying that the selected Case is indeed the one of interest.
- Click on the [Close] button to close the “Resolve Rule-based Constraint” form. The Name of the selected Case is saved to the database as the default selected Case to be used the next time that you invoke the “Resolve Rule-based Constraint” form, and the temporary Case _SELSCEN is deleted from the database.

5.2.7 Run Model Considerations for Rule-based Constraints

- Rule-based Constraints may be defined in the BASE scenario and in any non-BASE scenarios that the user wishes. As is the case with standard user-defined Constraints, the only rule-based Constraints that will be activated in a model run are those that are defined in one of the scenarios that comprise the model run.
 - When deciding in which scenario a particular rule-based Constraint is to be defined the user needs to bear in mind that a rule-based Constraint that is defined in the BASE scenario will be activated in every model run.
- The scope of a rule-based Constraint is the set of technologies in either the BASE scenario or in any of the non-BASE scenarios that comprise the model run. So for example if one of the “rules” for a rule-based Constraint is to select renewable electric technologies, then the set of (distinct) renewable electric technologies in the BASE scenario and in non-BASE scenarios that comprise the model run will be selected.
- At Run Model time for the Run (Case) named <Run>, all rule-based Constraints for each region <Region> that comprises the model run are resolved and written to a specially named DDS file, <Run>_RULES+<region>.DDS. That is, for say a 9 region run 9 such special DDS files will be created.

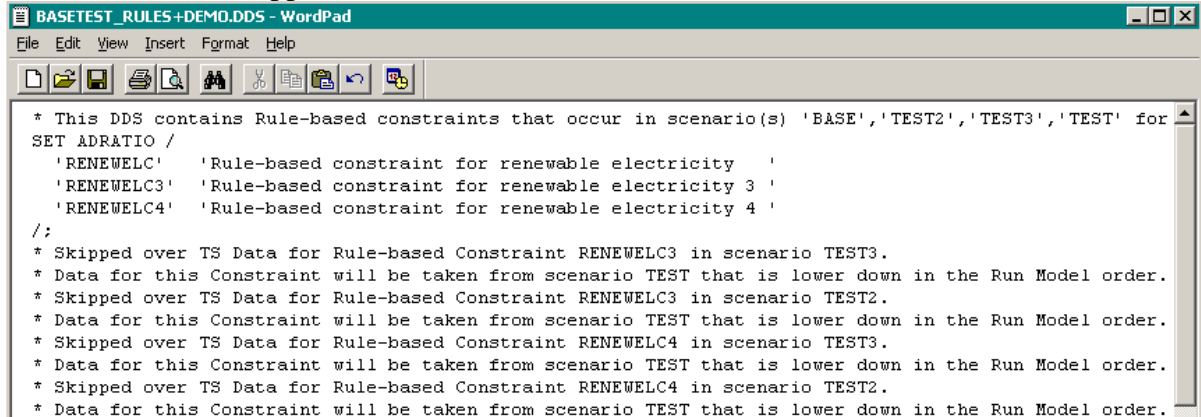
- New versions of the RegionTemplate.GEN and Template.GEN files ensure that the special RULES DDS files are \$INCLUDEd after the BASE DD and other non-BASE DDS files for the model run to ensure that all technologies involved in the constraints are previously defined.

5.2.8 Run Model Considerations for Rule-based Constraints – Fine Points

1. The user who specifies say both RAT_ACT and RATRULE_ACT parameter instances for a rule-based Constraint needs to understand how the RAT_ACT and RATRULE_ACT instances will be cumulated when the Constraint is resolved at Run Model time.
 - Where the technology that is specified for the RAT_ACT instance is not among the technologies selected by the “rule” associated with the RATRULE_ACT instance, the individual RAT_ACT rows generated when the Constraint is resolved will simply comprise the RAT_ACT row for this technology together with the RAT_ACT rows generated for each technology that satisfies the “rule” associated with the RATRULE_ACT instance.
 - Where the technology that is specified for the RAT_ACT instance is one of the technologies selected by the “rule” associated with the RATRULE_ACT instance, it is less clear what the individual RAT_ACT rows that are generated when the Constraint is resolved should comprise, *or indeed whether this situation should be brought to the user’s attention as a likely error*. Two alternate possibilities come to mind for the technology that is specified for the RAT_ACT instance, namely:
 - (a) The explicitly provided RAT_ACT row would be used, and the RATRULE_ACT row ignored so far as this technology is concerned; or
 - (b) The explicitly provided RAT_ACT row and the RATRULE_ACT row would both be used, with the numeric coefficients obtained by adding the numeric coefficients for the RAT_ACT and RATRULE_ACT instances together.

The current ANSWER code resolves such a Constraint in the manner described at (b) above, that is, the explicitly provided RAT_ACT row and the RATRULE_ACT row are both used.
2. What happens at Run Model time if a particular rule-based Constraint has Time Series rows associated with it in **more than one** of the scenarios that comprise the model run? For manageability, only the Time Series rows associated with this Constraint for the scenario that is lowest down in the Run Model order are used, and Time Series rows associated with this Constraint for scenarios that are higher up in the Run Model order are skipped over (ignored).
 - NOTE: It is only in respect of rule-based Constraints that data rows for scenarios that are higher up in the Run Model order are skipped over. The user is reminded that the general rule in ANSWER is that data rows for each Run Model scenario are written to that scenario’s <ScenarioName>+<Region>.DDS file, and so the effect at Run Model time is that data rows for each successive scenario in the Run Model order are merged with those for scenarios that are higher up in the order, rather than being overwritten or ignored.
3. Where a particular rule-based Constraint has Time Series rows associated with it in more than one of the scenarios that comprise the model run, a message is written to the special run

RULES DDS file informing the user as to each rule-based constraint and scenario for which data has been skipped over:



```
* This DDS contains Rule-based constraints that occur in scenario(s) 'BASE','TEST2','TEST3','TEST' for
SET ADRATIO /
'RENEWELC' 'Rule-based constraint for renewable electricity '
'RENEWELC3' 'Rule-based constraint for renewable electricity 3 '
'RENEWELC4' 'Rule-based constraint for renewable electricity 4 '
/;
* Skipped over TS Data for Rule-based Constraint RENEWELC3 in scenario TEST3.
* Data for this Constraint will be taken from scenario TEST that is lower down in the Run Model order.
* Skipped over TS Data for Rule-based Constraint RENEWELC3 in scenario TEST2.
* Data for this Constraint will be taken from scenario TEST that is lower down in the Run Model order.
* Skipped over TS Data for Rule-based Constraint RENEWELC4 in scenario TEST3.
* Data for this Constraint will be taken from scenario TEST that is lower down in the Run Model order.
* Skipped over TS Data for Rule-based Constraint RENEWELC4 in scenario TEST2.
* Data for this Constraint will be taken from scenario TEST that is lower down in the Run Model order.
```

In the above example, the database contained Time Series rows for rule-based Constraints RENEWELC3 and RENEWELC4 in scenarios TEST2, TEST3 and TEST. As can be seen from the top line of the run RULES DDS file, the scenario order is BASE, TEST2, TEST3, TEST with scenario TEST the lowest down in the Run Model order. So for example when the rule-based Constraint TS data for RENEWELC3 in scenario TEST3 is encountered, the following lines are written to the run RULES DDS file:

```
* Skipped over TS Data for Rule-based Constraint RENEWELC3 in scenario TEST3.
* Data for this Constraint will be taken from scenario TEST that is lower down
in the Run Model order.
```

4. For user convenience, the Time Series data for rule-based Constraints are put out to the run RULES DDS file grouped by rule-based Constraint and with an initial comment line indicating from which Run Model scenario the TS data was taken. So in the above example, the TS data for Constraint RENEWELC3 is put out as follows:

TS Data follows for Rule-based Constraint RENEWELC3 taken from scenario TEST

TABLE NRAT_RTY2		1990	2000	2010	2020
'RENEWELC3'	'LO'	EPS	EPS	EPS	EPS
TABLE NRAT_ACT					
'E01'	'RENEWELC3'	-0.06	-0.06	-0.06	-0.06
'E10'	'RENEWELC3'	-0.06	-0.06	-0.06	-0.06
'E14'	'RENEWELC3'	-0.06	-0.06	-0.06	-0.06
'E21'	'RENEWELC3'	-0.06	-0.06	-0.06	-0.06
'E30'	'RENEWELC3'	-0.06	-0.06	-0.06	-0.06
'E31'	'RENEWELC3'	.88	.88	.88	.88
'E32'	'RENEWELC3'	.88	.88	.88	.88
'E35'	'RENEWELC3'	.88	.88	.88	.88
'E3D'	'RENEWELC3'	.88	.88	.88	.88
'E4G'	'RENEWELC3'	-0.06	-0.06	-0.06	-0.06
'E4H'	'RENEWELC3'	-0.06	-0.06	-0.06	-0.06
'E6A'	'RENEWELC3'	-0.06	-0.06	-0.06	-0.06
'E6B'	'RENEWELC3'	-0.06	-0.06	-0.06	-0.06
'E6C'	'RENEWELC3'	-0.06	-0.06	-0.06	-0.06
'E6D'	'RENEWELC3'	.88	.88	.88	.88
'E82'	'RENEWELC3'	-0.06	-0.06	-0.06	-0.06
'EHL'	'RENEWELC3'	-0.06	-0.06	-0.06	-0.06

* TS Data follows for Rule-based Constraint RENEWELC4 taken from scenario TEST

TABLE NRAT_RTY2		1990	2000	2010	2020
'RENEWELC4'	'LO'	EPS	EPS	EPS	EPS
TABLE NRAT_ACT					
'E01'	'RENEWELC4'	-0.11	-0.11	-0.11	-0.11
'E30'	'RENEWELC4'	-0.11	-0.11	-0.11	-0.11

For Help, press F1

5.3 Enhancing ANSWER's Trade Tab to handle Bilateral Trade

This section describes changes to the ANSWER interface to permit easier handling of bilateral trade links. See *ANSWER Load Templates version 5 - Description of Use* for a description of Version 5 of the ANSWER Load Templates, which allows for the display of Bilateral Trade parameters on TechData upload sheets, permitting the user to specify Bilateral Trade between regions of a multi-region model in spreadsheet form.

5.3.1 Overview

To provide improved facilities for defining new bilateral trade links and for browsing, deleting and editing existing bilateral trade links, what was previously called the **Trade** tab in ANSWER has been renamed the **BiTrade** tab. Whereas the old Trade tab displayed both BiLateral Trade and Global Trade data (and results), the new BiTrade tab displays only BiLateral Trade data (and results). A completely new format is adopted for the top half of the screen that as well as

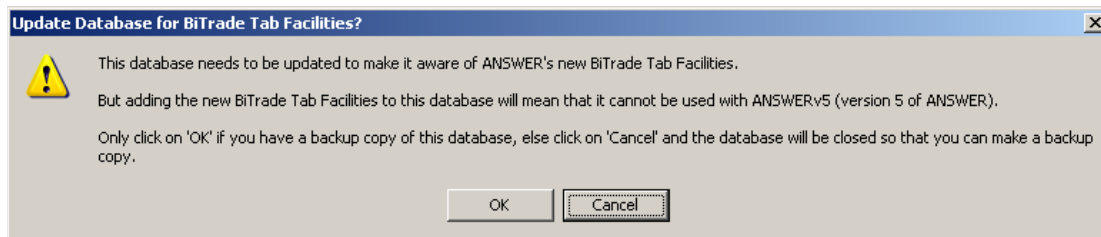
providing improved facilities, is more consistent with the operation of the top half of the screen on most other ANSWER tabs.

Since it is not possible to specify Global Trade data on the renamed BiTrade tab, new facilities are provided to conveniently specify Global Trade data from the Parameter tab. Also, while it is not possible to view Global Trade results on the renamed BiTrade tab, existing facilities enable Global Trade data to be viewed from the Parameter tab. See the Appendix for details.

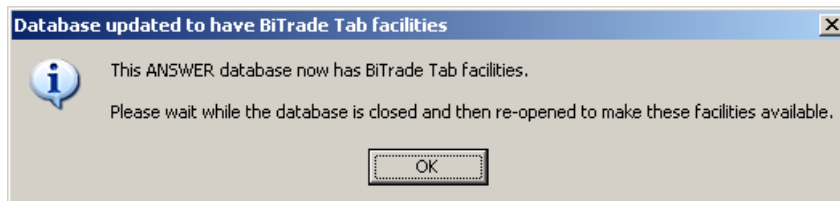
The enhancements to ANSWER's Trade Tab described in this document are available in ANSWER version 6.1.1 and higher.

5.3.2 Updating an ANSWER Database to be aware of the new Bilateral Trade Facilities

When you open an ANSWER database with ANSWER version 6.1.1 or higher, ANSWER checks whether the database is aware of the new bilateral trade facilities, and if it is not the following message appears, inviting you to update the database so that it is aware of the new facilities:



Assuming that you have a backup copy of the database, click on the [OK] button. After a couple of seconds, a message box confirms that the database has been updated to have these facilities:

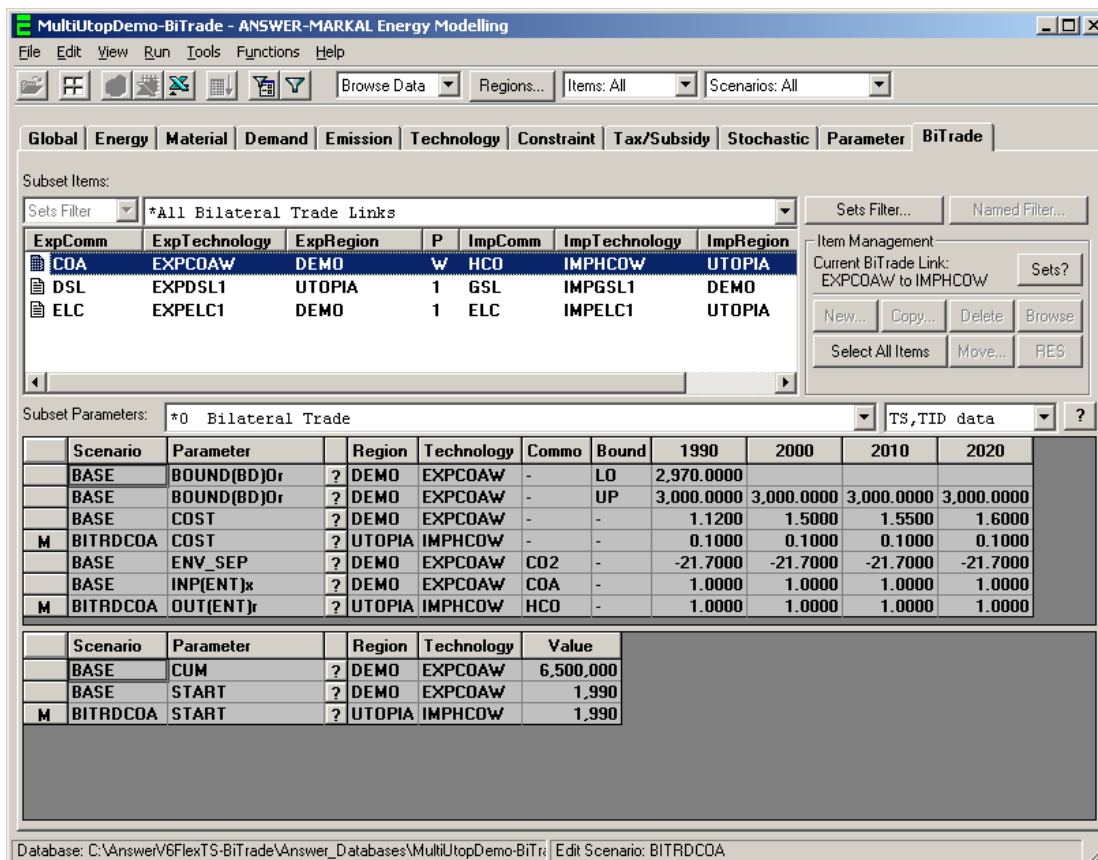


As indicated by the message, simply click on the [OK] button, and wait while the database is closed and then re-opened with these facilities now available.

Note that if you click on the [Cancel] button when the message appears inviting you to update the database, ANSWER closes the database. This means that if you want to work with an ANSWER database using version 6.1.1 or higher, you must update the database to be aware of the new bilateral trade facilities.

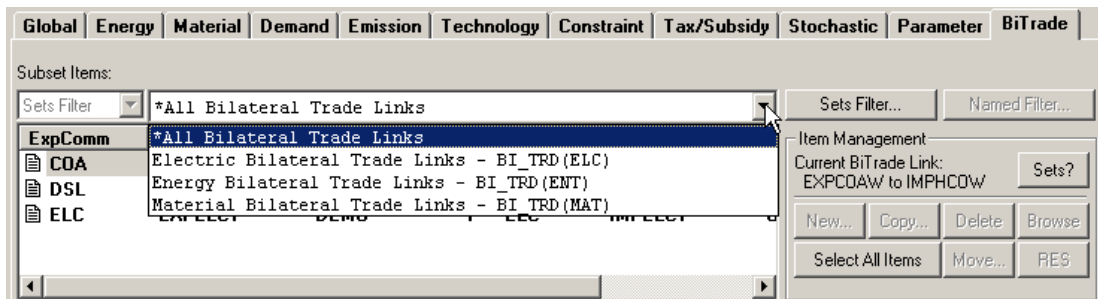
5.3.3 Items Listview on BiTrade Tab Populated with Bilateral Trade Links

On the new format **BiTrade** tab, the Items listview is populated with Bilateral Trade Links, with other changes following as a consequence of this fundamental change.

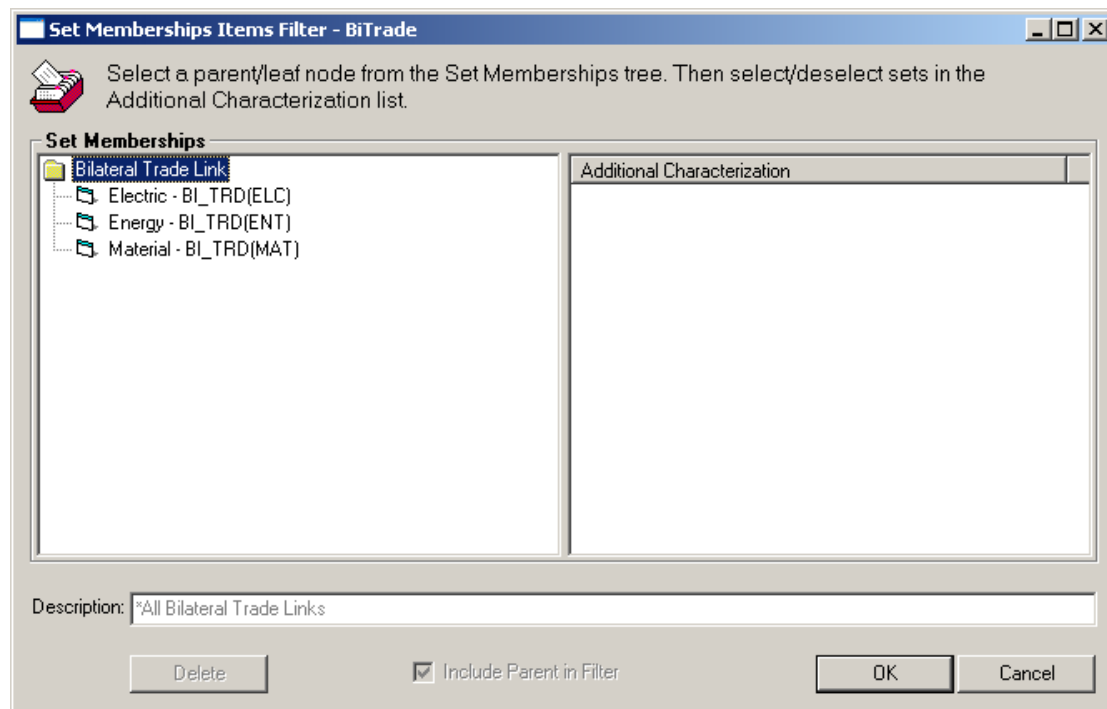


5.3.4 Some Notes about the Items Listview on the BiTrade Tab

1. The Export Commodity Name appears as the first column (ExpComm) in the Items listview (rather than the ExpRegion column) so that the user can quick-key to the Export Commodity of interest. This is considered to be a more useful order for the columns than to have the ExpRegion column as the first column, and is consistent with other ANSWER tabs where the Name column appears first and the Region column appears second.
2. The screen snapshot above displays the default “*All Bilateral Trade Links” setting of the Subset Items combobox. Alternate settings for this combobox are available so that the bilateral trade links that are displayed in the Items listview can be filtered so that just Electric (BI_TRD(ELC)) or just Energy (BI_TRD(ENT)) or just Material (BI_TRD(MAT)) Bilateral Trade Links are displayed:



Alternatively, the filtering of the bilateral trade links that are displayed in the Items listview may be achieved by clicking on the **Sets Filter...** button to bring up the following form:



3. The bilateral trade links that are displayed in the Items listview may also be filtered by using the **Regions...** button in the toolbar row. Where the **Regions...** button is used on the BiTrade tab to select a subset of regions whose data is to be displayed, a bilateral trade link will be displayed if either its Export region or its Import region is in this subset of regions (and subject also to any filtering that will apply if the Subset Items combobox is not on its default “*All Bilateral Trade Links” setting).

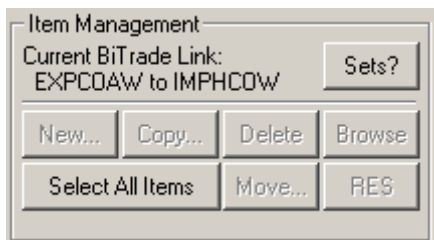
Thus to display bilateral trade links involving a single region (either bilateral trade links that involve *exporting* from that region to other regions, or that involve *importing* into that region from other regions) use the **Regions...** button to select the single region desired.

4. The default sort order for BiTrade links in the Items listview is Export Commodity, Export Technology, Export Region, Import Commodity, Import Technology, Import Region (or loosely speaking the default sort order is Export Commodity then Export Region). If you click in the ExpRegion column header in the BiTrade Items listview, the BiTrade links in the Items listview are rearranged to appear in the sort order Export Region, Export Commodity, Export Technology, Import Commodity, Import Technology, Import Region (or loosely speaking the sort order becomes Export Region then Export Commodity). If you then click in the ExpComm column header, the BiTrade links in the Items listview are rearranged to appear in the default sort order.

5. No attempt is made to determine a Modified Status for BiTrade links.

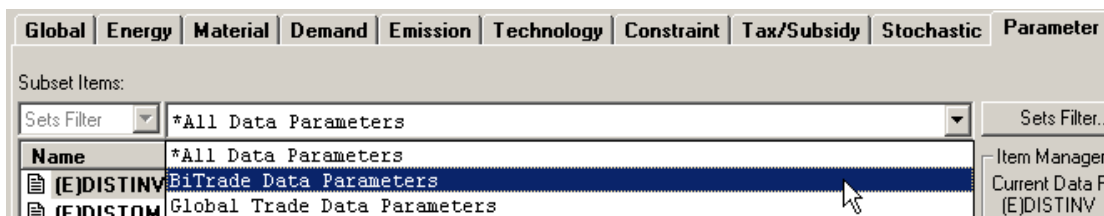
5.3.5 Operation of buttons in Item Management frame on the BiTrade Tab

1. In ANSWER version 6.1.1, the new BiTrade tab only provides facilities for *browsing* bilateral trade data, and consequently most of the buttons in the Item Management frame are disabled, as follows:

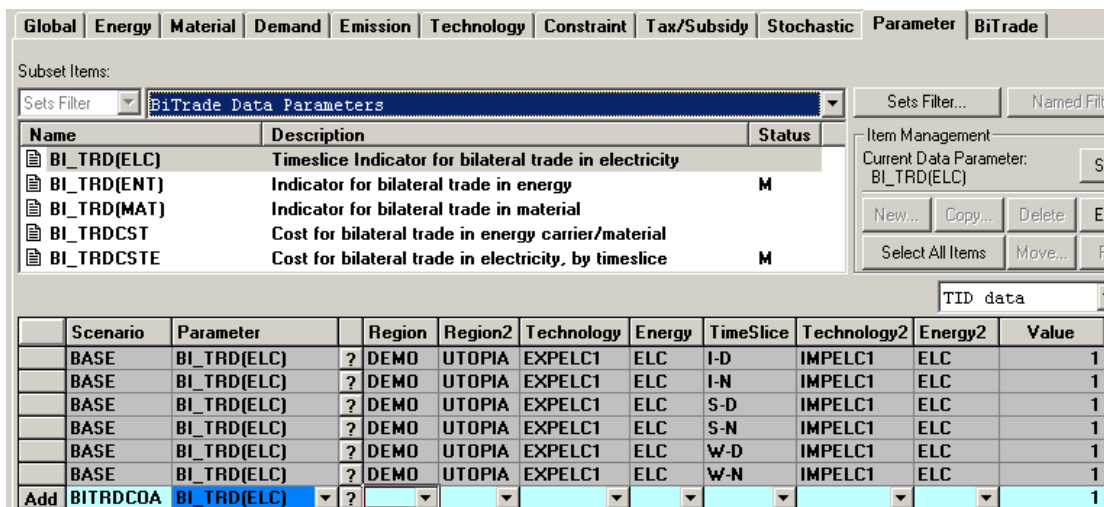


In subsequent ANSWER versions, facilities for *editing* bilateral trade data will be provided on the BiTrade tab, and so the [New...], [Copy...], [Delete], [Edit...] and [Move...] buttons will be enabled. Given the special needs of handling bilateral trade links, the forms that are displayed for [New...], [Copy...], [Delete], [Edit...] and [Move...] will be quite different from those that are displayed for most other tabs.

2. Note however that in ANSWER version 6.1.1, it is still possible to create new bilateral trade links and to delete existing bilateral trade links from the Parameter tab. This is most conveniently done by going to the Parameter tab and using the Subset Items combobox to subset down to a new “BiTrade Data Parameters” setting:

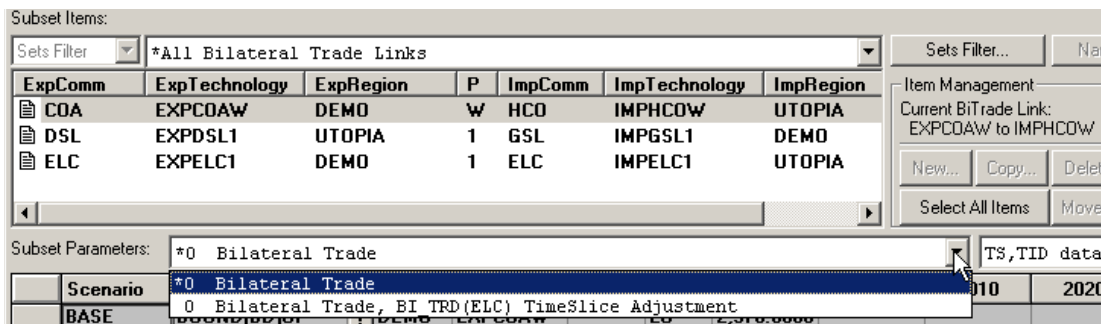


so that the listview displays only the following five bilateral trade data parameters:

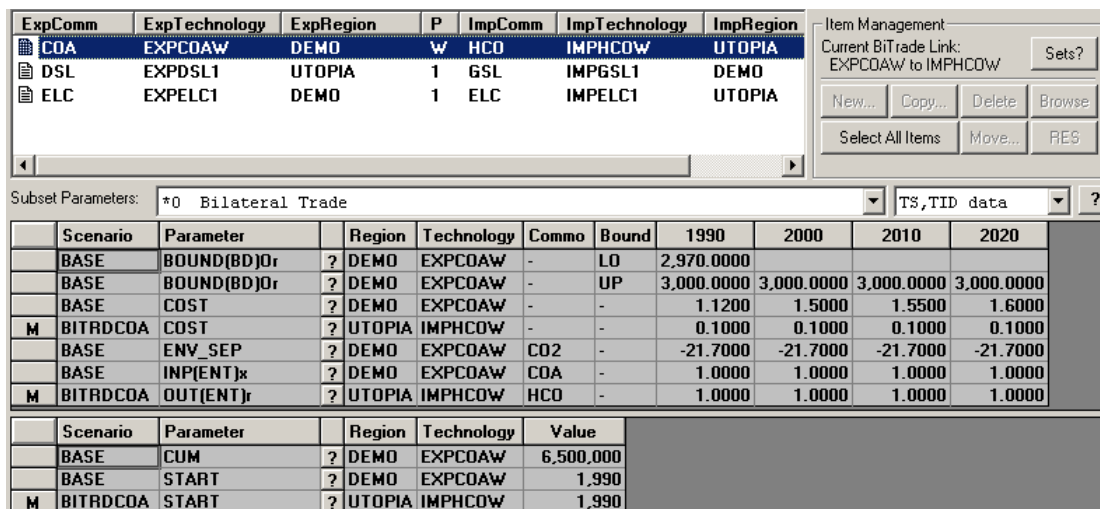


5.3.6 Data displayed in TS and TID data spreads on BiTrade Tab

1. For the new BiTrade tab, the bottom half of the screen still contains the familiar TS and TID data spreads. But these spreads now display different parameters than those previously displayed on the old Trade tab. Two Subset Parameter settings are now provided, as indicated below:



2. As a matter of user convenience, on the default “Bilateral Trade” setting the TS and TID data spreads now display all data for the Export and Import technologies involved in the bilateral trade link/links that are selected in the BiTrade Items listview. The screen snapshot below shows the data displayed where the selected bilateral trade link is from EXPCOAW in region DEMO to IMPHCOW in region UTOPIA:



We see that TS and TID data for both EXPCOAW in region DEMO and IMPHCOW in region UTOPIA is displayed.

3. As has already been noted above, in ANSWER version 6.1.1 only data *browsing* facilities are provided on the new BiTrade tab, and so it is not possible from the BiTrade tab to edit the TS and TID data that is displayed for Export and Import technologies involved in a bilateral trade link.

In subsequent ANSWER versions, facilities for *editing* the TS and TID data that is displayed for Export and Import technologies will be provided on the BiTrade tab, including use of the AddRow to create new parameter instances for the Export and Import technologies.

4. Many users may find that they need to use the alternate Subset Parameters setting of “Bilateral Trade, BI_TRD(ELC) TimeSlice Adjustment” only infrequently, if at all. Where the selected BiTrade Link is an electric link (that is, BI_TRD(ELC)), this setting displays the TimeSlices in which electric trade is possible:

ExpComm	ExpTechnology	ExpRegion	P	ImpComm	ImpTechnology	ImpRegion
COA	EXPCOAW	DEMO	W	HCO	IMPHCOW	UTOPIA
DSL	EXPDSL1	UTOPIA	1	GSL	IMPGSL1	DEMO
ELC	EXPELC1	DEMO	1	ELC	IMPELC1	UTOPIA

Scenario	Parameter	Region	1990	2000	2010	2020			
BASE	BI_TRD(ELC)	DEMO	UTOPIA	EXPELC1	ELC	I-D	IMPELC1	ELC	1
BASE	BI_TRD(ELC)	DEMO	UTOPIA	EXPELC1	ELC	I-N	IMPELC1	ELC	1
BASE	BI_TRD(ELC)	DEMO	UTOPIA	EXPELC1	ELC	S-D	IMPELC1	ELC	1
BASE	BI_TRD(ELC)	DEMO	UTOPIA	EXPELC1	ELC	S-N	IMPELC1	ELC	1
BASE	BI_TRD(ELC)	DEMO	UTOPIA	EXPELC1	ELC	W-D	IMPELC1	ELC	1
BASE	BI_TRD(ELC)	DEMO	UTOPIA	EXPELC1	ELC	W-N	IMPELC1	ELC	1

By default BI_TRD(ELC) links are created with electric trade possible in all TimeSlices, as for the EXPELC1 to IMPELC1 BI_TRD(ELC) link displayed above.

In ANSWER version 6.1.1, the “Bilateral Trade, BI_TRD(ELC) TimeSlice Adjustment” setting allows the user to easily *browse* the TimeSlice instances that are associated with a BI_TRD(ELC) link.

In subsequent ANSWER versions, the user who wishes to restrict trade for a BI_TRD(ELC) link to a subset of all TimeSlices will be able to do so by deleting BI_TRD(ELC) TimeSlice instances from the TID data spread for TimeSlices where trade is not desired; and conversely, the user who has deleted some BI_TRD(ELC) TimeSlice instances for a BI_TRD(ELC) link and then wishes to reinstate them will be able to do so by using the AddRow.

5.3.7 Results handling on BiTrade Tab

For the new BiTrade tab, all Bilateral Trade Results (but not Global Trade Results) are displayed in the TS spread (there are no TID Bilateral Trade Results Parameters), for the Subset Parameters setting “Bilateral Trade”, as indicated below:

ExpComm	ExpTechnology	ExpRegion	P	ImpComm	ImpTechnology	ImpRegion	Statu
COA	EXPCOAW	DEMO	W	HCO	IMPHCOW	UTOPIA	
DSL	EXPDSL1	UTOPIA	1	GSL	IMPGSL1	DEMO	
ELC	EXPELC1	DEMO	1	ELC	IMPELC1	UTOPIA	

Case	Parameter	Region	Region2	Technology	Energy	TimeSlice	Technology2	Energy2	1990	2000	2010	2020
BITRDCOA	MR_BITRD(ELC).M	DEMO	UTOPIA	EXPELC1	ELC	I-D	IMPELC1	ELC	0.00	0.00	0.00	0.00
BITRDCOA	MR_BITRD(ELC).M	DEMO	UTOPIA	EXPELC1	ELC	I-N	IMPELC1	ELC	0.00	0.00	0.00	0.00
BITRDCOA	MR_BITRD(ELC).M	DEMO	UTOPIA	EXPELC1	ELC	S-D	IMPELC1	ELC	0.00	0.00	0.00	0.00
BITRDCOA	MR_BITRD(ELC).M	DEMO	UTOPIA	EXPELC1	ELC	S-N	IMPELC1	ELC	0.00	0.00	0.00	0.00
BITRDCOA	MR_BITRD(ELC).M	DEMO	UTOPIA	EXPELC1	ELC	W-D	IMPELC1	ELC	0.00	0.00	0.00	0.00
BITRDCOA	MR_BITRD(ELC).M	DEMO	UTOPIA	EXPELC1	ELC	W-N	IMPELC1	ELC	0.00	0.00	0.00	0.00
BITRDCOA	R_TSEPELC.L	DEMO	-	EXPELC1	-	I-D	-	-	0.00	2.00	2.00	0.00
BITRDCOA	R_TSEPELC.L	DEMO	-	EXPELC1	-	I-N	-	-	2.00	0.00	0.00	0.00
BITRDCOA	R_TSEPELC.L	DEMO	-	EXPELC1	-	W-N	-	-	0.00	0.00	0.00	0.00
BITRDCOA	R_TSEPELC.L	UTOPIA	-	IMPELC1	-	I-D	-	-	0.00	2.00	2.00	0.00
BITRDCOA	R_TSEPELC.L	UTOPIA	-	IMPELC1	-	I-N	-	-	2.00	0.00	0.00	0.00
BITRDCOA	R_TSEPELC.L	UTOPIA	-	IMPELC1	-	W-N	-	-	0.00	0.00	0.00	0.00
BITRDCOA	R_TSEPELC.M	DEMO	-	EXPELC1	-	I-D	-	-	0.28	0.00	0.00	0.00
BITRDCOA	R_TSEPELC.M	DEMO	-	EXPELC1	-	I-N	-	-	0.00	0.00	0.00	0.00
BITRDCOA	R_TSEPELC.M	DEMO	-	EXPELC1	-	S-D	-	-	23.80	22.07	20.38	0.00
BITRDCOA	R_TSEPELC.M	DEMO	-	EXPELC1	-	S-N	-	-	2.49	0.21	0.16	0.00
BITRDCOA	R_TSEPELC.M	DEMO	-	EXPELC1	-	W-D	-	-	0.28	0.00	0.00	0.00

The BiTrade Items listview is populated on the basis of distinct instances of Results Marginals for MR_BITRD(ELC), MR_BITRD(ENT), MR_BITRD(MAT). So above, MR_BI_TRD(ELC).M Results Marginals are used both to populate the BiTrade Items Listview with the EXPELC1 to IMPELC1 link, and in addition the TS spread displays the values for these marginals.

In addition, the other Bilateral Trade Results parameters such as R_TSEPELC.L and R_TSEPELC.M are displayed on the “Bilateral Trade” Subset Parameters setting.

5.3.8 Specifying Global Trade Data and Viewing Global Trade Results

As noted above, whereas in earlier versions of ANSWER it was possible to specify all Global Trade data parameters, and view all Global Trade results parameters, from the Trade tab, it is not possible to specify or view Global Trade data and results from the renamed BiTrade tab. This Appendix details how to conveniently specify Global Trade data parameters, and view Global Trade results parameters, from the Parameter tab.

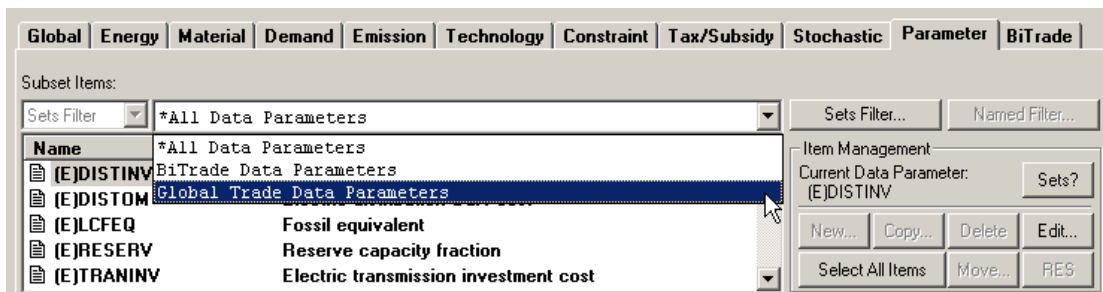
5.3.8.1 Specifying Global Trade Data Parameters

The Global Trade data parameters that are no longer accessible from the BiTrade tab are listed below first showing TS and then TID parameters:

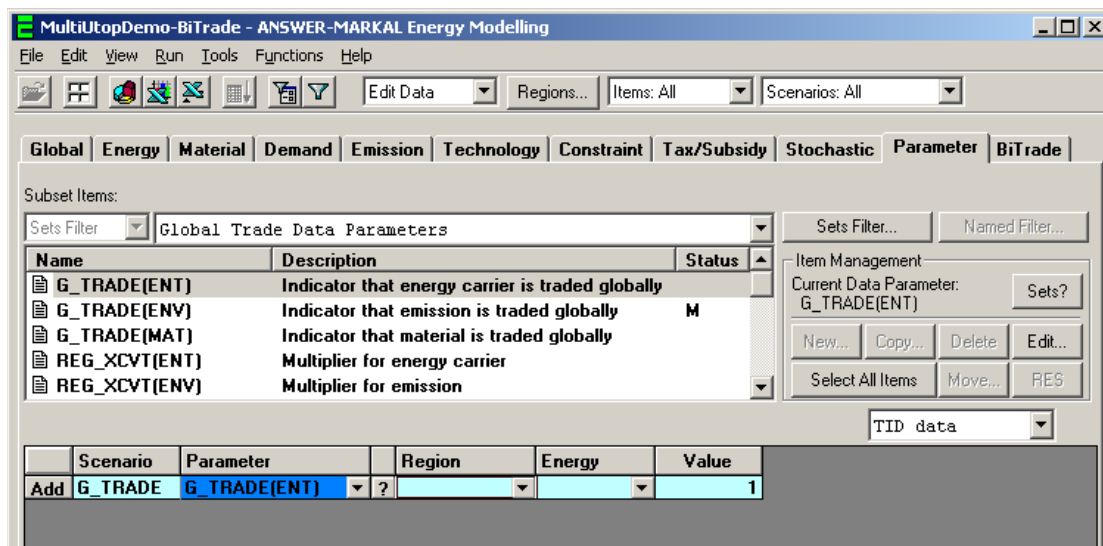
TRD_BND(ENT)exp	Bound on exports for global trade in energy carrier
TRD_BND(ENT)imp	Bound on imports for global trade in energy carrier
TRD_BND(ENV)exp	Bound on exports for global trade in emission
TRD_BND(ENV)imp	Bound on imports for global trade in emission
TRD_BND(MAT)exp	Bound on exports for global trade in material
TRD_BND(MAT)imp	Bound on imports for global trade in material
TRD_COST(ENT)	Cost for global trade in energy carrier
TRD_COST(ENV)	Cost for global trade in emission
TRD_COST(MAT)	Cost for global trade in material
G_TRADE(ENT)	Indicator that energy carrier is traded globally
G_TRADE(ENV)	Indicator that emission is traded globally
G_TRADE(MAT)	Indicator that material is traded globally
REG_XCVT(ENT)	Multiplier for energy carrier
REG_XCVT(ENV)	Multiplier for emission
REG_XCVT(MAT)	Multiplier for material
REG_XMACRO	MACRO multiplier
REG_XMONY	Monetary unit conversion
TRD_FROM(ENT)	Year from which global trade in energy carrier can occur
TRD_FROM(ENV)	Year from which global trade in emission can occur
TRD_FROM(MAT)	Year from which global trade in material can occur

5.3.8.2 New “Global Trade Data Parameters” Subset Items setting on Parameter Tab

A new “Global Trade Data Parameters” Subset Items setting is provided on the Parameter tab that displays all of the above Global Trade data parameters (and only these parameters), so that instances of these parameters may be conveniently defined, browsed, deleted and edited.



That is, to define a new Global Trade data parameter instance, or to browse, delete or edit existing instances go to the Parameter tab and use the Subset Items combobox to select “Global Trade Data Parameters”. The Items listview will be populated with all the Global Trade parameters, and the screen might appear as follows:




Standard ANSWER facilities may then be used to define new parameter instances (via the AddRow), or to browse, delete or edit existing instances.

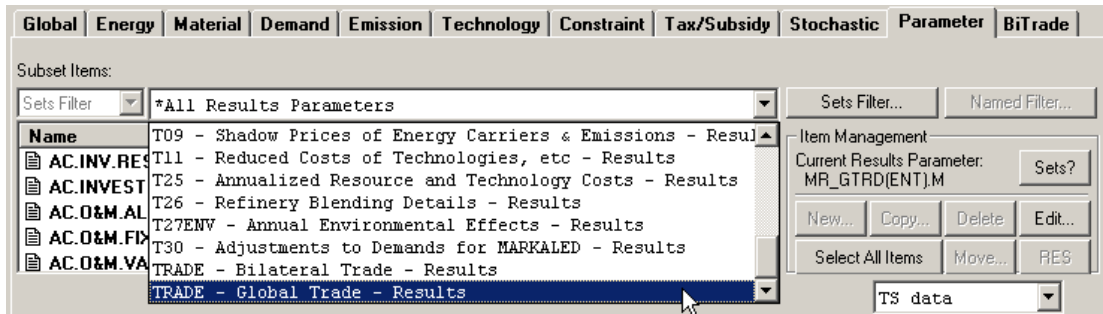
5.3.8.3 Viewing Global Trade Results Parameters

The Global Trade results parameters that are no longer accessible from the BiTrade tab are listed below. They are all TS parameters.

MR_GTRD(ENT).M	Global Trade in Energy: Marginal
MR_GTRD(ENV).M	Global Trade in Emission: Marginal
MR_GTRD(MAT).M	Global Trade in Material: Marginal
R_GTRD(ENT)exp.L	Region Global Trade: Export of Energy: Level
R_GTRD(ENT)exp.M	Region Global Trade: Export of Energy: Marginal
R_GTRD(ENT)imp.L	Region Global Trade: Import of Energy: Level
R_GTRD(ENT)imp.M	Region Global Trade: Import of Energy: Marginal
R_GTRD(ENV)exp.L	Region Global Trade: Export of Emission: Level
R_GTRD(ENV)exp.M	Region Global Trade: Export of Emission: Marginal
R_GTRD(ENV)imp.L	Region Global Trade: Import of Emission: Level
R_GTRD(ENV)imp.M	Region Global Trade: Import of Emission: Marginal

R_GTRD(MAT)exp.L	Region Global Trade: Export of Material: Level
R_GTRD(MAT)exp.M	Region Global Trade: Export of Material: Marginal
R_GTRD(MAT)imp.L	Region Global Trade: Import of Material: Level
R_GTRD(MAT)imp.M	Region Global Trade: Import of Material: Marginal

As was the case with version 5 of ANSWER, the Global Trade results parameters may be viewed from the Parameter tab by invoking the “TRADE – Global Trade – Results” Subset Items setting (or by using the  button to invoke this setting):



5.3.8.4 Accessing “Global Trade Data Parameters” on Alternative Tabs

The Global Trade data parameters may also be accessed from other tabs, if that is more convenient for the user:

The 6 Global Trade data parameters that involve energy carriers (ENT) may now all be accessed from the Energy tab, on the (default) “Energy Carrier, Specific” Subset Parameters setting. Previously these 6 parameters were accessible from the Energy tab, on the (perhaps little known) “Energy Carrier, Related Trade” Subset Parameters setting.

Similarly the 6 Global Trade data parameters that involve materials (MAT) may now all be accessed from the Material tab on the (default) “Material, Specific” Subset Parameters setting, and the 6 Global Trade data parameters that involve emissions (ENV) may now all be accessed from the Emission tab on the (default) “Emission, Specific” Subset Parameters setting.

The 2 Global Trade data parameters REG_XMACRO and REG_XMONY may now be accessed from the Global tab.

6. Support for Integration and Subsequent Flexing of US9r

{Section pending discussion with EPA}

