

Pakistan Integrated Energy Model (Pak-IEM)

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Final Report Volume III Users' Guide

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And

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LIST OF ACRONYMS

AC	Air conditioning
ACT	Activity variable
ADB	Asian Development Bank
AEDB	Alternative Energy Development Board
AF	Availability Factor
AGR	Agriculture sector
BAU	Business As Usual (scenario)
BY	Base Year
CAP	Capacity variable
CNG	Compressed Natural Gas
COM	Commercial sector
CPLEX	Linear Programming solver used by Pak-IEM TIMES model
DE	Direct Edit
DEM	Set of all energy service demands
DISCO	Distribution (Electricity) Company
EFF	Efficiency parameter
EIA	Energy Information Administration
ELC	Power sector
ELCC	Electricity commodity - central station
ELE	Set of Electric Power Plants
ETSAP	Energy Technology Systems Analysis Programme
EYB2007	Energy Year Book of Pakistan 2006-7
GAMS	General Algebraic Modeling System
GDP	Gross Domestic Product
GHG	Greenhouse gas
GoP	Government of Pakistan
GW	Gigawatts
GWh	Gigawatt hours
HP	Horsepower
HSD	High Speed Diesel
IEA	International Energy Agency
IND	Industry sector
IRG	International Resources Group
KWh	Kilowatt hours
LDO	Light Diesel Oil

LO	Lower (minimum) bound
LNG	Liquefied natural gas
LPG	Liquefied Petroleum Gas
MAT	Set of all material (commodity) carriers
MDR	Model Design Report
MIP	Mixed Integer Programming
MW	Megawatts
NCAP	New Capacity Investments variable
NRG	Set of all energy (commodity) carriers
OPTCR	Optimization Criteria
Pak-IEM	Pakistan Integrated Energy Model
PEPCO	Pakistan Electric Power Company
PJ	Petajoules
REF	Reference
RES	Reference Energy System
RSD	Residential sector
SnT	Sets and Tables File
SUP	Supply (or upstream) sector
TA	Technical Assistance
TIMES	The Integrated MARKAL EFOM System
TRN	Transportation sector
UC	User Constraint
UP	Upper (maximum) bound
VEDA	VErsatile Data Analyst
VEDA-BE	VEDA Back End (VBE)
VEDA-FE	VEDA Front End (VFE)
WAPDA	Water and Power Development Authority

I. Introduction

A. Purpose and Organization of this Users Guide

The purpose of this User's Guide is to complement other documentation of VEDA (Versatile Data Analyst) and TIMES (The Integrated MARKAL EFOM System) by explicitly describing how the Pakistan Integrated Energy Model (Pak-IEM) is organized and used. It is not meant to be exhaustive in nature; rather, it is designed to be used in conjunction with the Pak-IEM Final Report: Volume I – Model Design to describe the various aspects of Pak-IEM within the VEDA/TIMES paradigm. The goal is to provide a roadmap to the overall model and data organization and a step-by-step manual for managing Pak-IEM.

This User's Guide is organized as follows:

- Section I provides the context of this guide and its relationship to other related documentation.
- Section II gives a basic overview of the input templates, explaining their organization and content.
- Section III provides guidelines on how to best use VEDA to manage the templates and oversee the model data.
- Section IV provides procedures for running the model and creating new scenarios.
- Section V describes the processes for examining the results of model runs and preparing these for presentation.

In addition, the Appendices present the mechanics of working with the PIEM_Analytics workbook and a series of Exercises for new users.

The User's Guide is designed to be used both as a training manual, whereby a new user can proceed through the entire manual to become familiar with Pak-IEM and how to work with it, and as a reference guide for experienced users who need to review or refresh themselves on a particular aspect of using Pak-IEM.

B. Relationship to Related Documentation

The main Pak-IEM model documentation can be found in the Pak-IEM Final Report: Volume I – Model Design, where the general structure and philosophy underlying the model are presented, as well as the sector specifics, with an emphasis on data needed and the associated data sources. This Guide assumes that the reader is familiar with the Pak-IEM Model Design, and focuses instead of the practical maintenance and use of Pak-IEM.

This guide is also complemented by the VedaSupport website – <http://www.kanors.com/vedasupport/> – maintained by KanORS, the VEDA developer. The website, while a work in progress, provides the main resource with respect to the philosophy and use of VEDA. All Pak-IEM experts should make time to browse through the VedaSupport website.

Figure 1 depicts the VEDA/TIMES modeling environment, where VEDA-Front_End (VEDA-FE or VFE) manages the input data templates and submits the model runs to TIMES, where GAMS (General Algebraic Modeling System) generates the model mathematics and solves it, passing the results to VEDA-Back_End (VEDA-BE or VBE), which assists with the analysis of the model results - including passing them to the Pak-IEM Analytics workbook (discussed later).

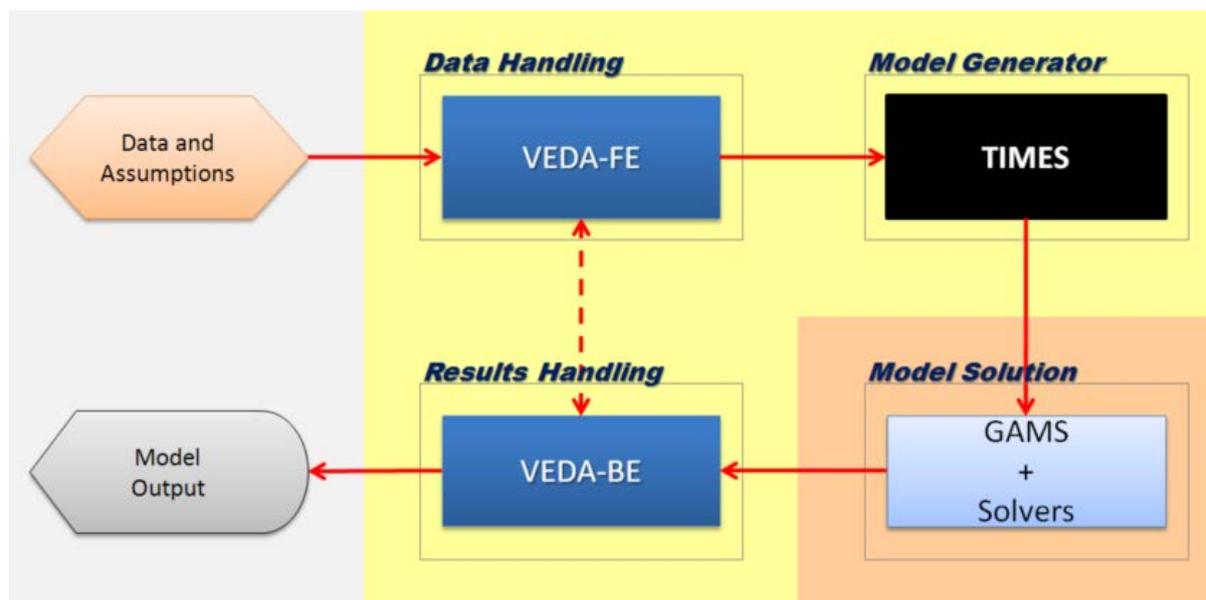


Figure 1: Overview of the VEDA/GAMS/TIMES Modeling Environment

Since the VedaSupport site serves as the official VEDA documentation, and will be kept current with new features and examples added as needed, this Guide will not repeat the information contained there. Instead, the Guide will draw attention to the most often used facilities in VEDA to be employed when working with Pak-IEM.

II. Organization of the Data and Model

A. Folder Structure and Content

Each model maintained by VEDA resides in its own folder (drive:\VEDA\VEDA_Models\PIEM_TMPL_<date>) for handling the model input and associated internal VEDA-FE (VFE) databases, and has a related VEDA-BE (VBE) database set for handling the results in another folder (drive:\VEDA\VEDA_BE\Databases\PIEM_VBE. For Pak-IEM each time a major new release of the model is created the <date> tag is to be updated. [Whenever a new PIEM_TMPL_<date> archive is distributed it should be deposited and unRAR/ZIPed in the \VEDA\VEDA_Model folder, as the <app_input> folder saved when creating the archive. Similarly, when a VBE is exchanged as PIEM_VBE(<date>) it is deposited in the \VEDA\VEDA_BE\Databases folder and then extracted into the PIEM_VBE folder (be sure to rename the current PIEM_VBE beforehand).

Within the VEDA philosophy and structure the files and folders in \VEDA\VEDA_Models\PIEM_TMPL_<date> root folder are organized along the lines described here, with specific naming conventions.

- **\VEDA_Models\PIEM_TMPL_<date>** – corresponds to the root folder containing various model templates described below.
 - **Pak-IEM_EnergyBalance** – has the initial year (2006-7) energy balance, which is linked to from other templates. [Note, NOT a VEDA related file, strictly internal to Pak-IEM.]

- **VT_PAK¹<sector>** – Base Year (BY) templates containing the representation of the initial year energy system. There is one file for each energy system sectors handled, for Pak-IEM these include AGR, COM, ELC, IND, RSD, SUP and TRN (as discussed further in Section II.C).
- **SysSettings** – containing special VEDA declarations for the region(s), time periods, time-slices, and import settings.
- **BY_Trans** – with the default declarations for certain values for certain parameters.
- **xModelTemplateTracking<date>** – contains a table listing each of the Pak-IEM input templates and is intended to be used as part of (manual) version control producers to keep track of which member of the Planning Team is responsible for the various templates, and the status of each template with respect to undergoing revisions. See Addendum B for a discussion of template version control. [Note, NOT a VEDA related file, strictly internal to Pak-IEM.]
- **\Databases** – contains the internal VEDA databases managed by VFE and should not be touched.
- **\Logs** – contains any reports generated by VFE during import/synchronization (SYNC) of the templates, and should not be open here (as they can be viewed via the Navigator).
- **\SubRES_TMP** -
 - **SubRES_NewTech** – contains the complete characterization for all new resource and technology options. [The **_Trans** transformation file is only relevant for multi-region models, and therefore is not used for Pak-IEM.]
- **\SuppXLS**
 - **Scen_REF-<qual>** – contains information for tailoring of the reference scenarios, such as power plant build rates, demand sector fuel share evolution, etc.
 - **Scen_Pol-<alt scenario>** – are files containing alterations applied to the B-Y/SubRES files to shape the Reference Scenario and define sensitivity runs.
 - **Template-Scen_ZPolicyRuns<date>** – is a tool to facilitate the creation of new or modified policy scenarios, and can be used to create new policy scenario files.
 - **\Demand** – holds the demand allocation series mapping in **Dem_Alloc_Series** and the three **ScenDem_DEM_PIEMLow/Med/Ref** demand projection scenarios.

A diagram of the Pak-IEM folder structure is provided in Figure 2. Note that the BY templates are hyperlinked to data in the Energy Balance template, which is not directly read by VFE. The Energy Balance and BY templates should be rather stable and are not likely to change until it is decided to update the model base year sometime in the future.

¹ Note that VFE requires the explicit naming convention of VT_ followed by the Region (as declared in the SysSettings file and sector name (with any other characters desired, though not used for Pak-IEM).

Similarly, it is not anticipated that the BY_Trans or SysSettings templates will require adjustment, other than when new Milestone (run) periods are declared (by means of the VFE Advanced menu).

Finally, the Model Template Tracking file is stored in this folder, but is for internal use by the Planning Team to assist in tracking changes to the model templates. Likewise, the Policy Runs Scenario Template is stored with the actual scenario files, but it is a tool for generating scenarios and is not read by VFE.

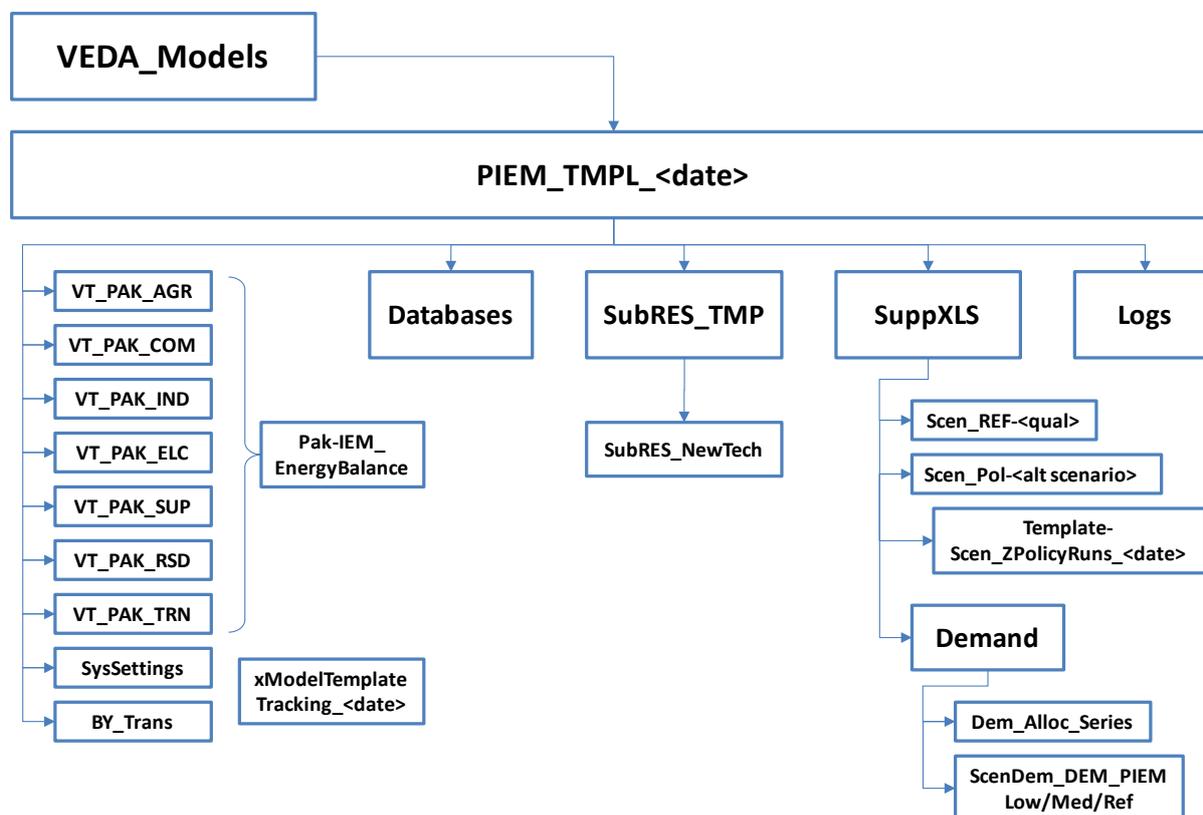


Figure 2: Pak-IEM VEDA_FE Template Structure

B. Pak-IEM Workbook Template Organization

The templates constitute structured Excel workbooks that contain all the data embodied in Pak-IEM, from original data sources reference material, to the various component declarations and characterizations required for a TIMES model. Each BY, Demand and NewTech workbook is organized along similar basic themes, as shown in the Figure 3 example, which is taken from the power sector workbook. Each template consists of four main worksheet types, tabs color coded as noted below:

- **Status Information (reddish)** – contains descriptive information related to each workbook. This includes version control (Legend), Reference Energy System diagram (RES), units (Conversion/Currency) and the like.
- **Declaration (green)** – the components of the RES (commodities and processes) are declared in this workbook. Operational characteristics of each component need to be explicitly declared to indicate how it fits into the energy system (e.g., is a technology a power plant or demand device, is a commodity an energy carrier or an emissions).
- **Source Data (blue)** – the actual source data from which model inputs are derived, including transformations as necessary.

- **VEDA Load Sheets (yellow)** – those input sheets actually processed by VEDA, where the data from the Source Data sheets are prepared for the model and needed direct entries are made.

Template Guide	
Name	Description
RES	Reference energy system diagram
ReviewComments	Table to input comments based on template review
Commodities	Definition of commodities used in sector (Model load table)
Processes	Definition of processes used in sector (Model load table)
Existing_PP	Model load table, characterising end use technologies across different subsectors
Sector_Grid	Model load table, characterising grids (and associated EFF losses)
Sector_Fuels	Model load table, characterising technologies that track sector fuel consumption
Emissions	Model load table, with subsector emission factors for CO ₂ , NO _x (BY only) and SO ₂ (BY only)
NTDC_ElecMtkData	Data from NTDC (2008), Electricity Marketing Data (Power System Statistics)
PEPCO_Therm	Data provided directly from PEPCO on thermal plants
PEPCO_HydelProd	Data provided directly from PEPCO on seasonal hydro generation
KESC_Therm	Power plant information provided directly by KESC
PakEYB2007-ELECT	Power sector information from EYB 2007
PakEYB2007-Renewable	Renewable generation information from EYB 2007
NEPRA_HydroCosts	Hydro O&M costs (calculated by MEC based on NEPRA tariff determination)
NEPRA_ThermalCosts	Thermal plant O&M costs (calculated by MEC based on NEPRA tariff determination)
Nuclear PP	Information on nuclear generation existing plants
Conversion	Energy conversion units
Currency	Currency exchange and deflator values [to be included]
Legend	
Status information	
Overview / Model declarations	
Model load sheets	
Primary data sheets (used in load)	
Miscellaneous	

Figure 3: Color Coding and Example of Worksheets in a Pak-IEM Input Template

It is also worth noting that there is a color convention for text and values used in the templates, to allow the analyst to quickly understand whether the text / value are fixed, linked or calculated. This convention is shown below.

User input (and fixed text)
Linked cell reference
Calculation

C. Relationship of the Templates and the Pakistan Energy System

The templates are organized along sector lines, where the base year data is kept in dedicated workbooks, the new technology options are on sector sheets in the NewTech workbook, and the demands for all sectors are found in the demand workbooks with sheets for each sector. The first two groups are then supplemented by information in the REF-<area> for tailoring of the Reference scenario. For the most part each of the workbooks is self-contained, with two exceptions. Firstly, all the BY sector workbooks are linked to the Energy Balance workbook, as the starting point or cross-check for the sector consumption as part of the calibration process. Secondly, the SySettings file (described in section II.D.1) is also linked to the Energy Balance workbook, to get data on model global assumptions. In addition, as discussed in Section II.D, some of the BY data is "grabbed" for the REF-<area> workbook by means of the VEDA "fill table" facility as part of establishing future fuel shares. These shares inhibit the system from changing too dramatically with respect to what energy

is consumed and in which sectors across the energy system (though this can be readily adjusted for sensitivity runs as desired).

This section goes on to describe in more detail the organization of each of the workbooks, explaining both the role of each of the types of worksheet and highlighting the key parameters that the analyst may want to change in view of new information. For specific linkages to different data sources, the analyst is encouraged to review the templates in detail (which are transparent as linked directly to data assumptions), and refer to the Pak-IEM Final Report: Volume I – Model Design for a description of the key sources.

1. Role of the Energy Balance and Relationship to the Sectors

The workbook *PakIEM_EnergyBalance-2007* contains all of the information relating to Pakistan's energy balance in 2006/07, the year that the Pak-IEM model is calibrated to, based upon the Pakistan's **Energy Year Book**. This workbook, which is not a model template, plays a very important role in ensuring that the model base year is fully calibrated to real world statistics. This is done by linking all BY (base Year) templates to this workbook, specifically the worksheet *EnergyBalance*. When Pak-IEM is re-calibrated in the future, this would be the key worksheet to update. This should be relatively straightforward, as the structure of the Energy Year Book data workbook has been retained.

The *EnergyBalance* worksheet holds the majority of the core energy balance numbers, including final consumption by sector and fuel consumed for electricity generation. Therefore, BY templates only link to this specific worksheet. The majority of the other worksheets provide additional data from Pakistan's **Energy Year Book 2006-7** (EYB2007), to supplement the core energy balance data sheet, *PakEYB2007_MIX*.

All of the BY templates contain information from the energy balance workbook in the same location – rows 3-5 on the main sector worksheet i.e. those worksheets that contain the primary model tables for upload into the VEDA-FE database. For example, for *VT_PAK_COM*, the relevant worksheet is labeled *Commercial*. To ensure the integrity of the links to the BY templates, the energy balance workbook must always be labeled *PakIEM_EnergyBalance-2007*. This relationship can be seen in Figure 4 below for natural gas to the sector.

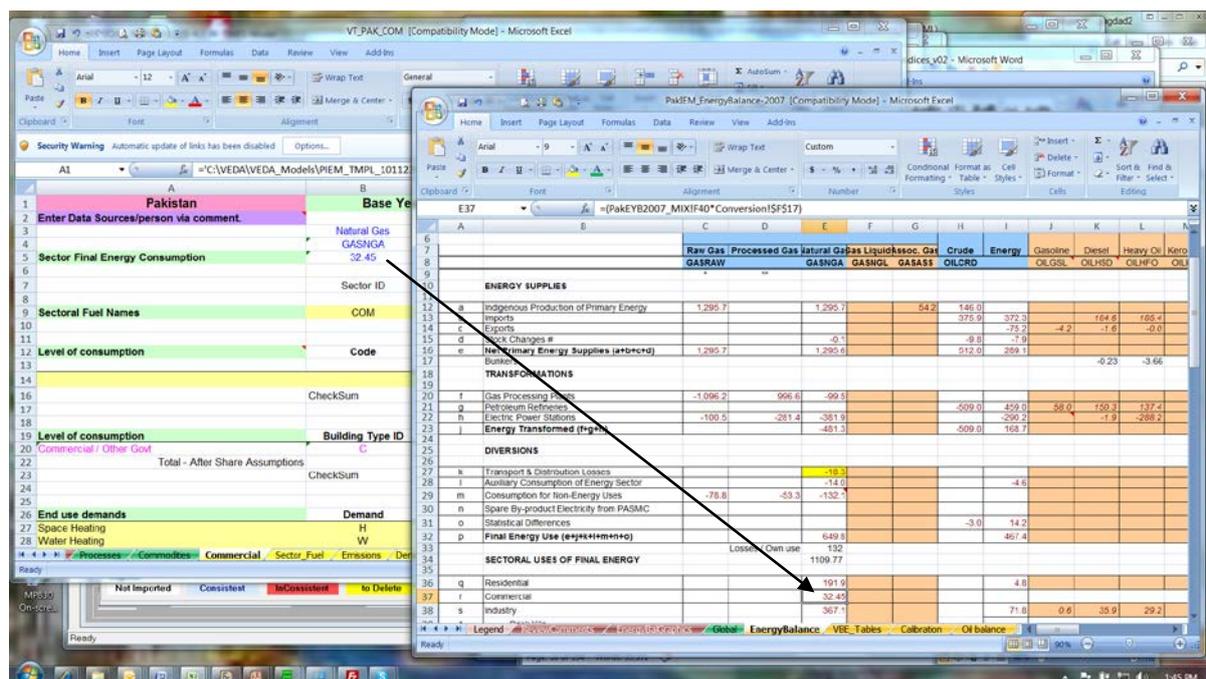


Figure 4: Commercial Sector Template Link to BY Energy Balance 2006/7

The energy balance does not provide all of the information required on energy consumption in Pakistan. It is estimated that there is a level of illegally imported (black market) diesel in Pakistan. This has been estimated as the difference between the diesel total reported in the **Energy Year Book** and that calculated (based on bottom-up approaches) for use in agriculture and transport sectors (see section VI.E in the Model Design Report for further information). The calculations to estimate and cross-check diesel consumption can be found in worksheet *Oil balance*. The second source of energy not captured in the **Energy Year Book** is biomass, a fuel of major importance for cooking, particularly in rural communities. The detailed estimates of biomass consumption can be found in worksheet *BiomassEstimates*. Section III.D of the Model Design Report provides a description of the how biomass consumption has been estimated in the base year.

In addition to holding energy balance information, this workbook is also used to check the model calibration. Two worksheets are used for this purpose – *VBE_Tables* and *Calibration*. The calibration checking process is described in detail in section IV.B of this report.

The energy balance workbook also has a worksheet labeled *Global*, which provides many of the global parameters required in the model including:

- Timeslice structure
- Discount rate
- Peak Reserve Margin

This information is used in the model through links with the *SySettings* file (described in section D below). Therefore any changes to these global assumptions should be made in *PakIEM_EnergyBalance-2007/Global*.

2. Supply and Upstream

The resource supply and upstream sector (in the base year) is characterized in model template *VT_PAK_SUP*. There are four worksheets containing model load tables (worksheet tab shaded yellow), listed in Table 1.

Table 1. Model Load sheets in VT_PAK_SUP

Worksheet	Description
SupplySteps	Model data to characterize domestic energy resources, import and export options available in 2006/07. ² Key parameters include: <ul style="list-style-type: none"> • Energy costs • Annual production bounds • Cumulative reserves
Pipelines	Represents the capacity of the gas transmission and distribution network.
Upstream	Characterizes the existing refinery plants as individual technologies. Key parameters include: <ul style="list-style-type: none"> • Refining capacity • Product slate (current and future) • Efficiency of process • Operating costs
Emissions	Model table to aggregate all CO2 commodities to a single commodity TOTCO2 (using COMAGG attribute). It is useful to have a single commodity for tracking total emissions or setting single (multi-sectoral) emission targets.

All worksheets in the BY template are listed and briefly described in the *Legend* worksheet.

SupplySteps worksheet

This worksheet characterizes energy resources into the following groups:

- Indigenous production of energy by regional resource (rows 18-60)
- Imports (rows 61-73)
- Exports (rows 74-84)
- Renewable resources (rows 85-98);
- Others (nuclear, black market diesel, load shedding, materials) (rows 99-114)

To ensure that the level of resources in the BY corresponds to that shown in the energy balance (rows 5-7), *V: CheckSum* are included in the worksheet. For example, the *CheckSum* in cell Q40 compares the BY domestic oil production based on the field level data with the aggregate energy balance values. If the values do not match, an error is flagged, with the difference value indicating the degree of divergence.

A full description of the data assumptions is provided in the Pak-IEM Final Report: Volume I – Model Design. Here we describe the mechanism for changing those assumptions, where the analyst has new or improved data to use.

Domestic production of energy

The key parameters that the analyst needs to be aware of for each domestic energy resource are listed in the tables below. These tables should provide the analyst with an understanding of where to make changes to the range of data assumptions in the worksheet.

Table 2. Modeling of Domestic Oil Resources

Data assumption	Description
Maximum (UP) share of associated gas	Based on current year production levels, and assumed for future years of production a cumulative level is entered in Col-F. Associated gas always likely to be taken by the model (despite not being forced) because low additional cost.

² Resources options available in future years (but not utilized in the base year) are characterized in *SubRES_NewTechs/SUP*.

Energy costs	In absence of production costs, prices are factored on import prices in the <i>CommodityPrices</i> sheet (currently 70%, see cell N17), see next section. Projected forward based on WEO 2009 – see cells D13:K13. Associated gas production adds additional 5% of crude cost (see cell N47).
Annual production limits	Data from <i>Oil Fields, Prod. & Res. and Ass. Gas Fields, Prod. & Res.</i> is brought to Col-Q for the base year. These values would need to be changed if model base year is adjusted and re-calibrated. Future year production limits (column S) are based on maximum annual production levels from Government projections from <i>CRD-Projections-DGPC</i> . These are relaxed in future years based on factors in column Z.
Reserves	Column V sets the proven reserves based on information in the worksheet <i>Oil Fields, Prod. & Res. and Ass. Gas Fields, Prod. & Res.</i> Reserves can be increased based on a reserves factor (column X), to account for new discoveries in future years. [Note the use of FLO_CUM, not CUM, as limit needs to be on commodity where two commodities (GASASS / OILCRD) are produced.]

Table 3. Modeling of Domestic Gas resources

Data assumption	Description
Energy costs	Prices based on average well head prices by region, sourced from <i>Gas Fields, Prod & Res. Projected forward based on WEO 2009</i> – see U13:X13, are gathered on the <i>CommodityPrices</i> sheet and linked to the load sheet, see next section.
Annual production limits	Base year levels from <i>Gas Fields, Prod & Res</i> appear in Col-Q. Future year production limits in Col-S are based on maximum annual production levels from Government projections (see <i>NG-Projections-DGPC</i>). These are relaxed in future years based on factors in columns Z-AA.
Reserves	Reserve levels are in column W as taken from <i>Gas Fields, Prod & Res.</i> Reserves can be increased based on a reserves factor (column X), to account for new discoveries in future years.

Table 4. Modeling of Domestic Coal Resources

Data assumption	Description
Energy costs	Prices based on EYB2007 information is gathered on the <i>CommodityPrices</i> worksheet from <i>Coal Price Projections</i> , and include projections to 2015, see next section.
Annual production limits	Base year levels from <i>Coal Reserves 2007</i> appear in Col-Q. Future limits (columns S-U) are arbitrary due to a lack of available information but take account particularly of the energy needs of the domestic brick kiln industry in future years. A UC in <i>REF-ELC</i> (worksheet <i>Supply</i>) controls the future share of domestic coal production based on the BY shares. This ensures that a single region cannot provide all Pakistan's domestic coal requirements (as markets are region specific)

Reserves	Reserve values in column W are taken from <i>Coal Reserves 2007</i> . [Note that the Thar resource is included in the SubRES_NewTechs template.]
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Commodity Price Assumptions

The *CommodityPrices* worksheet is where the current and future prices for domestic and imported commodities are established, as described in the above tables. This is a critical sheet that will be subject to ongoing updates as current domestic prices and international projections are published. It is therefore important that this is adequately described.

Oil

- The imported crude price in 2006/07 is estimated in worksheet *Comb-CRD-Prices*, based on information sourced from the EIA. The estimate uses weekly spot prices of different Middle East crudes to develop an annual average (see cell BF65).
- This price for imports is then projected forward based on WEO 2009 – see cells D13:K13.
- Due to lack of domestic crude production costs, the domestic price is set at 70% of the import price (based on the factor in cell N16). All fields assume this price.
- While this value may not be the exact price seen in the market, it serves the modeling purpose of ensuring lower domestic crude costs in the model. This issue has always got to be considered if changes to prices are introduced into the model.
- The projected domestic price is also based on the WEO 2009 estimates.
- Future development of the crude resource supply could include a supply cost curve and a move towards production costs, rather than the current import price proxy.

Oil products

- The price of domestic oil products seen in the model is endogenously calculated based on the imported / domestic crude price, and the annualized investment / O&M cost of domestic refineries.
- Imported oil product prices are based on Ex. Refinery prices from the Energy Year Book 2008 (see *EYB08_POLprice* / *EYB08_FOprice*), with a multiplier (of 1.2) to ensure import prices are higher than domestic prices (see cell N25 in *CommodityPrices*). Projected prices are based on the WEO 2009 estimates.
- Exports use the same price estimates as imports but have a multiplier of 0.6 to ensure that refineries do not switch operation to focusing on profit maximization through export sales (see cell N26 in *CommodityPrices*). The primary purpose of allowing exports is to allow the refinery sector to produce efficiently based on their product slate, allowing for excess production of specific oil products to be exported. [Note that export prices have to be expressed as negative values in the model load table.] All oil products can be both imported and exported. The only annual resource limits on imports / exports relate to base year estimates (column Q in *SupplySteps*), with an interpolation rule of -1 to ensure the bounds are not extrapolated.

Figure 5. CommodityPrices Worksheet

Natural Gas

- Unlike domestic crude, natural gas resource costs are based on wellhead prices associated with the different fields. For each region, these are “binned” into three cost categories, aligned with the resource zone. This is shown in worksheet *Gas Fields, Prod & Res*. This information is collated in cells D43:D45 of the *CommodityPrice* sheet.
- Domestic gas prices are projected forward, based on WEO 2009 projections.
- In the base year, there are no natural gas import options. However, such options are available in future years, and emerge as important resource options under the Reference case. The costs of imported natural gas are described in section 5 below, titled *New Technologies*.

Coal

- Coal prices for domestic coal are based on information in the EYB2007 (shown in worksheet *Coal Price Projections*), including projections out to 2015. Prices are differentiated between regions.
- Projections of domestic coal prices beyond 2015 are based on assumptions from European models (see cells V19:Z19).
- Import prices are currently set at 20% higher than the most expensive domestic resource. This estimate is calculated directly in the *SupplySteps* worksheet.

Other resources

For other resources, the analyst should be aware of the following assumptions:

- Annual biomass resources observed in 2006/07 are extrapolated to all future years (based on interpolation rule 5 – see column R). Prices can be found in *CommodityPrices*; note that the “free” resource is calculated as biomass price multiplied by reduction factor of 0.2 (in cell I62).
- Bagasse and MSW resources (current and projected per annum) are estimated in worksheet *BiomassSupplyData*.

- Imported and domestic nuclear resources are available. The current RES limits imports to existing and planned nuclear plant and uses domestic resources for future builds. No resource limits have currently been assumed.
- The base year level of black market diesel is sourced from *PakIEM_EnergyBalance-2007.xls/Oil balance*. Future levels of this resource are controlled by UC *SL_BMARKET_DSL* (found in scenario file *REF-DMD*). The price is set at +20% of the imported diesel price.
- The dummy load shedding technology is introduced in row 107. Shares allocate this dummy electricity to different sectors. A detailed description of the approach can be found in section IV.C.2 a) (4) of this report, under the description of how to set up the Reference scenario run.
- Technologies for material imports of coke and iron ore (for the iron and steel sector) can be found on rows 113:114.

Pipelines worksheet

This worksheet characterizes the current gas network capacity in Pakistan (see cell M15). It is simply the amount of gas coming on to the network in the base year divided by a utilization factor (cell R15, assumed to 95%). In terms of system losses, an efficiency factor is derived as the difference between total production and consumption covering pipeline and gas processing losses. [Note that the gas processing stage has not been modeled separately in this version of the model.]

Gas is supplied seasonally to meet different levels of demand during different periods of the year. Therefore, the pipeline technology (and resource processes) need to be defined as SEASON in the *Process* definition sheet. This is an important issue that needs to be kept in mind if the natural gas production and distribution parts of the RES are further developed.

Upstream worksheet

The refinery sector is characterized in this worksheet. Most of the assumptions in the worksheet relate to the base year. These include:

- Crude input level [cells S16:S22]
- Share of import / domestic crudes used [cells M16:N22]
- Refining capacity (based on maximum crude processing level) [cells U16:U22]
- Product output levels [cells T16:T22 for aggregate levels, cells C16:J22 for shares]
- Efficiency (cells W16-22). Note that the efficiency is input normalized for refinery processes (input over output), meaning that in modeling terms the input crude is designated the primary commodity group. In the process definition table (*Processes* worksheet), this is denoted by NRGI in the PrimaryCG column. Refineries are modeled this way due to the large number of output commodities.

However, there is a range of assumptions that could be changed for determining existing refinery operation in future years. Table 5 describes the key assumptions that the analyst may want to change in view of new or improved information. Some of the assumptions in the table are currently based on information provided by refineries, in worksheet *RefinerySuppliedData*.

Table 5. Flexible Assumptions in the Upstream Worksheet

Data assumption	Description
Capacity level in future years	Currently the capacity level is fixed over the model time horizon (column Q in the model load table). [A stock reduction factor in column X allows for the 2040 stock level to be adjusted; the stock level would then be interpolated between the BY and 2040. The interpolation rule is set in the <i>BY_Trans</i> file.]

Crude import versus domestic resource	The upper limit on import versus domestic crude use is set in cells O16:P22. This reflects current crude input shares but allows for more flexibility on input mix.
Product slate flexibility	Cells C36:J41 allow for the relaxation of the product output shares in future years, by around 10% in most cases except gasoline.
Minimum level of refinery operation	Column R of the model table sets the minimum level of refinery operation in future years. This level can be changed by adjusting the values in cells N26:N32.

3. Power Plants

The power generation sector (in the base year) is characterized in model template *VT_PAK_ELC*. There are two sector-specific worksheets containing model load tables labeled *Existing_PP* and *Sector_Grid*, discussed next.

***Existing_PP* worksheet**

Basic Structure

This worksheet handles all of the information relating to the existing power plants, each of which is characterized individually. With the exception of the plant retirement profile, the values in this worksheet are unlikely to need updating unless the model base year is changed. All of the key plant characteristics are based on reported data (columns E-M, except column J), drawing on data from the following worksheets (all of which is unpublished except the first worksheet listed):

- *NTDC_ElecMtkData* – Electricity Marketing Data (Power System Statistics), published by NTDC
- *PEPCO_Therm* – data for PEPCO thermal plants, and independent power producers (IPPs)
- *PEPCO_HydelProd* - data for WAPDA hydro plants
- *KESC_Therm* - data for plants on the KESC system
- *NEPRA_HydroCosts* – tariff data to determine O&M costs for hydro plant
- *NEPRA_ThermalCosts* – tariff data to determine O&M costs for thermal plant

Four sets (2007-2010) of availability factors for hydro plant are provided in columns N-Y (see worksheet *PEPCO_HydelProd*). The plant retirement profile is provided in columns Z-AU. For PEPCO thermal plant, the retirement profile is based on information provided by the Pak-IEM Planning team. For all other plants, it has been calculated based on typical lifetimes of different plant types, as provided in cells AP20:AP23 for IPPs and cells AO26:AQ26 for other plants.

Important associated user constraints on existing power plant operation are labeled UC_ExELEUtil<Plant Name>, and can be found in scenario file *Scen_REF-ELC/ForcedOperation*. These constraints ensure that existing plants operate at least at the level observed in the base year, subject to an analyst provided relaxation factor.

Other important constraints for this sector can be found in *Scen_REF-ELC/MinShare_Prod*:

- UC_ShareDualGasOil (row 11) forces a minimum level of centralized generation from gas, oil and dual-fueled plants.
- UC_ExELEUtil ETHSDENG-GEN-E (row 20) ensures minimum utilization of existing diesel generation, based on current year levels.
- UC_ExELEUtil Rental (row 26) ensures minimum utilization of rental plants (existing and new).

Calibration

Columns BB-BR are critical for ensuring that the fuel consumption from all of the individual plants is calibrated to the energy balance values. The first step is to calculate the fuel consumption by plant, based on the reported values – see columns BD-BI. The aggregate consumption values from these calculations are shown in cells BD107:BI107, with the difference from the energy balance in cells BD114:BI114. Based on this difference, an adjustment factor to apply to the efficiency values can be estimated; the adjusted efficiency factors are then used in the model load table to ensure calibration.

The calibration can be checked in worksheet *Calibration*. The VEDA-BE update routine can be used to update the table *CL_Power Plants Fuel Use and Generation*, and compare the aggregate values from the model output to the energy balance data, in cells Q63:V64.

Near term calibration (2007-2009) is also considered at the aggregate level, by forcing a minimum level of grid-based electricity. This is done through the use of LO activity bounds in *REF-ELC/MinShare_Prod* (see cells H32:H34).

Peak demand

It is important that the model captures the system's peak demand for electricity, as this has important implications for the type of generation options that need to be built. To achieve this, demand for energy services are specified by timeslice, in the scenario file *REF-FRs* described later in this report (see section IV.C.2). These determine when the peak demand for electricity occurs by aligning the timing and adding the amount of electricity called for by each of the demand activities in each timeslice; in the Pak-IEM model, it is in timeslice SP (summer peak) which has the highest aggregate demand for electricity.

The associated constraint in the model is the Peaking Reserve Constraint. This constraint imposes the requirement that the total capacity of all processes producing a commodity at each time period must exceed by a certain percentage the average demand in each time-slice, where the peak occurs thereby forcing the total amount of installed capacity. This percentage factor, the peak reserve factor, is set by attribute *COM_PKRSV* in *SySettings/Constants* according to the value entered on the *Pak-IEM_EnergyBalance/Global* sheet (15% for Pak-IEM). It ensures that the system has a certain degree of resilience (or spare capacity) to safeguard against factors that could lead to load shedding or black outs.

The constraint has to be turned on by putting a flag in the commodity definition table, in the field *PeakTS*, which is done in *VT_PAK_ELC/Commodities* for the main central electricity commodity (ELCC). This can be either ANNUAL if unsure of which timeslice the peak occurs (a peak equation is generated for every timeslice) or the name of the timeslice in which peak demand occurs if known with certainty.

Sector_Grid worksheet

The electricity grid is modeled in two main parts – transmission (*GTRANELC-E*) and distribution (*GDISTELC-E*). Both have efficiency factors, representing both technical and non-technical losses on the system; these values are calculated in cells C23:D23 in worksheet *Existing_PP*.

Due to the relatively high level of losses, the model appears to move away from the existing grid system quite quickly, investing in a much more efficient grid network. (Infrastructure investment costs may also be potentially too low, attracting investment). To prevent such unrealistic outcomes, lower activity bounds have been introduced (see column N-P) in the model load table, ensuring that the system operates at a minimum level.

The capacity of the system is expressed in terms of GW, based on the existing generation level (cell H21 in worksheet *Existing_PP*) and assumed utilization level (column R of the model load table). New plant build requires the system to invest in more network capacity, as the assumed utilization level is at 95%.

4. Demand Sectors

The main worksheet in each of the sector BY templates is labeled <Sector Name>, except for industry, which has a specific worksheet for each industry subsector. These worksheets contain the core model load table for each demand sector, and generally have a similar structure as described below.

- Energy balance information (at the top of the worksheet), sourced directly from the energy balance workbook, *PakIEM_EnergyBalance-2007*.
- Decomposition shares are located below the main energy balance estimates, either derived from a bottom-up stock-based approach or using a top-down estimation approach. These shares allocate the energy consumption (reported in the energy balance) to individual subsectors, and technology types within those subsectors.
- Below the decomposition shares is the model load table, which characterizes the individual technologies, including the energy they use (calibrated to the energy balance totals), base year capacity, efficiency, availability and O&M costs. From this table, the base year useful energy demand can be estimated. BY useful energy demands provide the seed value for the demand drivers, described in section 6 below.

In addition to the <Sector Name> and *Demand worksheets* just discussed, all BY templates also have VEDA-input worksheets labeled *Sector_Fuels* and *Emissions*. The *Emissions* worksheet simply allocates emission factors (CO₂, SO₂ and NO_x) to different technologies.

The *Sector_Fuels* worksheet defines technologies that track fuel consumption across the sector. These are often referred to as *X-Process* technologies, and are identified by a technology name built with an "X" and then sector/fuel e.g. XINDEL for electricity to the industry sector. In most cases, the technology capacity in the base year (defined using the parameter *Stock*) uses the annual consumption level. However, this is not the case for X-Processes tracking gas or electricity, which have a sub-annual temporal resolution. In these cases, the stock in the base year must reflect the maximum capacity at the seasonal (for gas) or daily timeslice level (for electricity). This stock value is therefore represented as the maximum consumption of energy in any given time period (divided by the period length i.e. fraction of the year). These calculations are undertaken below the main *Sector_Fuels* model table. These need to be re-calculated if sector timeslice shares (COM_FRs) are adjusted in the *Scen_REF-FRs*.

Finally, in worksheets <Sector Name> and *Sector_Fuels* there are a set of model tables containing the attribute *VA_SectFuelCons*. These tables collect information on energy consumption across different sectors in the base year, which is then used in user constraints (UCs) in the scenario file *REF-DMD* to control fuel switching rates (via FILL tables).³

4.1. Agriculture (AGR)

In template *VT_PAK_AGR*, the energy consumed in the agriculture sector is split between four subsectors – water pumping, tractors providing road haulage, tractors providing farm operations, and other uses, e.g. heating for buildings. To allocate energy use to each subsector, shares have been derived (see cells C15:F18) based on information from the 2004 Agricultural Census, provided in worksheet *MachineryCensusEstimates*.

These shares are applied to the energy balance values to derive the final energy consumption in each subsector (see cells C25:G28). The exception to the rule is for diesel,

³ Dummy technologies are used in conjunction with attribute *VA_SectFuelCons*. Because these dummy technologies only capture selected data, and are not part of the model RES, an INFORMATION error is observed on import of model templates in VFE.

the consumption of which is not provided in the Energy Year Book. Diesel consumption is therefore calculated directly from census data (see cell C10).

Table 6 lists the key data in the *MachineryCensusEstimates* worksheet, used as the basis for deriving subsector fuel consumption estimates. In general, the values that could be changed by the analyst are colored black, with yellow shaded cells. Pink colored values are calculations, based on the key source data from the census.

Table 6. Key Assumptions for Deriving Subsector Fuel Shares

SubSector	Source data	Additional description	Cell reference
Tractors	Stock by tractor size		B10:B15
	Tractor activity	This is the amount of time a tractor is typically used in a day, and number of days used per year.	C10:D15
	Activity type	These values attribute fraction of time tractors used to farm operations; the rest of the time is considered to be haulage.	F10:F15
	Efficiency	Efficiency is represented as average consumption per hour of use. Both farm operations and haulage have the same efficiency assumption.	M10:M15, P10:P15
	Activity time loss	The above factors allow for the calculation of fuel. A further adjustment is made to take account of time lost due to maintenance. Hours lost are calculated based on number of tractors and days out of operation.	B25:C31
Tubewells	Stock by fuel type	Stock values are further disaggregated into public and private sector – although these specific data are not used in the fuel consumption estimate.	B47:G48
	Diesel tubewell type	Split between high and low speed pumps; LDO assumed to be used in low speed and HSD in high speed pumps.	I48:J48
	Tubewell activity	This is the amount of time a tubewell is typically used in a day, and number of days used per year. ELC and DSL pumps are differentiated.	B56:E56
	Efficiency	Efficiency is represented as average consumption per hour of use (based on non-census sources).	B69:C69
	Non-working stock	Identify number of tubewells operational, allowing for adjustment to the stock level.	H54,K54

The model load table (from row 33) characterizes the generic technologies using energy in this sector. Most of the assumptions used are sourced from the census data, or other sources (see worksheet *TechnologyData*).

4.2. Commercial (COM) with government services & military

The structure and BY data for the commercial sector can be found in the *VT_PAK_COM* template. The sector models the following energy services:

- Space Heating
- Water Heating
- Space Cooling
- Cooking
- Lighting

- Refrigeration
- Miscellaneous Electric
- Other

A top-down approach is used to disaggregate energy balance estimates across the range of energy services (listed above). The share estimates are shown in rows 38-46 in the main *Commercial* worksheet, and the calculated fuel totals are shown in rows 57-65.

Fuel shares

Limited information is available to understand the use of energy by energy service across this sector. Most of the fuel share estimates are therefore based on expert judgment, working in conjunction with the Planning Team. Gas and electricity shares by energy service type are based on information from an analysis undertaken by Hagler Bailly for the ADB SEED project (see worksheet *FuelShares*).

Technology level data

Once energy consumption has been disaggregated across the different energy services, the individual technologies need to be characterized, for use in the model. The model load table, which holds this information, can be found between rows 78-136. All of the technology level data is based on assumptions from the US NEMS model (see worksheet *US NEMS COM Data*).

4.3. Industry (IND) by subsector

The industry sector in 2007 is represented in the *VT_PAK_IND* workbook. It contains an Industry overview sheet and model data sheets for each of the following subsectors, the source data for which is contained in separate subsector worksheets:

- Iron and Steel
- Textiles
- Sugar
- Cement
- Brick kilns
- Fertilizer
- Other Industry

The individual subsector worksheets tend to be structured as follows (starting at the top of the worksheet):

- Subsector consumption, and allocation of energy consumption to different processes (sourced from the industry worksheet)
- Tables listing the types of process, or commodities used in the subsector (for labeling purposes)
- Base year demand (model load) table (note that for other sectors these values are found on a separate worksheet labeled *Demand*)
- Core model load tables

The supporting data for the subsector can be found below the core model load tables. For most subsectors, a RES diagram can be found in the relevant worksheet.

Industry worksheet

This worksheet provides an overview of energy consumption for the sector, broken down by each of the subsectors. Fuel shares (cells C14:N20) allocating fuel types to subsectors have been calculated based on a range of sources (as the Energy Year Book does not generally report at subsector level, the exceptions being the cement sector and Pakistan Steel)

- Natural Gas – based on information provided from gas distribution companies in worksheet *GasConsumption*
- Electricity – based on data estimates from the DISCO consumption database, as provided in worksheet *ELCConsumption*
- Coal – sector-based estimates are provided directly from the EYB2007
- Oil – based on a range of sector-specific sources, including ENERCON MIS database (see worksheet *ENERCON_MIS*) as no central source available

Data on captive generation capacity, relevant to many of the subsectors, can be found in the *CaptiveGen* and *UDI* worksheets. *CaptiveGen* is the primary source, based on a survey of distributors to different industries, undertaken by MEC. *UDI* is the Platt's based information on generation capacity in Pakistan. Further information on these sources can be found in the Pak-IEM Final Report: Volume I – Model Design. The particulars for establishing the base year data for each subsector are discussed in the sections that follow. [There are RES diagrams on each of the sector sheets, along the lines of the Pakistan Steel RES shown below.]

Iron and Steel

This subsector is split into a further three subsectors:

- Integrated steel works (Pakistan Steel). Model load tables are in rows 75-136. All data assumptions are sourced from worksheet *PakSteel*
- Independent steel producers (represented by trade associations) – see rows 146-155
- Other steel producers – see rows 157-164. This subsector takes account of energy use in the sector but not accounted for by the statistics provided by the independent sector associations

Pakistan steel is the only sector in Pak-IEM to be fully modeled at the individual process level, producing four different outputs – pig iron, cast billet, steel products and other processes. The first three are represented in the sector Demand table (cells A63:C72) in terms of million tonnes of output (Mt) while the other category captures unallocated energy consumption.

Whilst in most sectors, the efficiency parameter (EFF) is used to express the efficiency of the process, in this and other industry subsectors an Input / Output approach is used, primarily because of the fact that for many processes there is more than one input and output. Another important issue is that all of the input values have to be expressed on the basis of a specific output (where there are multiple outputs). This is done by defining the Primary Commodity Group (in the Process worksheet) as the specific commodity for that process against which all inputs are referenced. For example, all inputs for the coke oven process (*I&S Integrated Coke ovens Existing*) are relative to the output of coke product (*MICOK*), but not coke oven gas (*IISCOG*).

Another important aspect of how the sector is modeled is that processes are integrated. Without the coke ovens producing coke and coke oven gas, other parts of the integrated process could not function. For example, coke is required for the blast furnace and sinter plant, while coke oven gas is used in the captive generation plant. This can be readily seen in the Pak-Steel RES below.

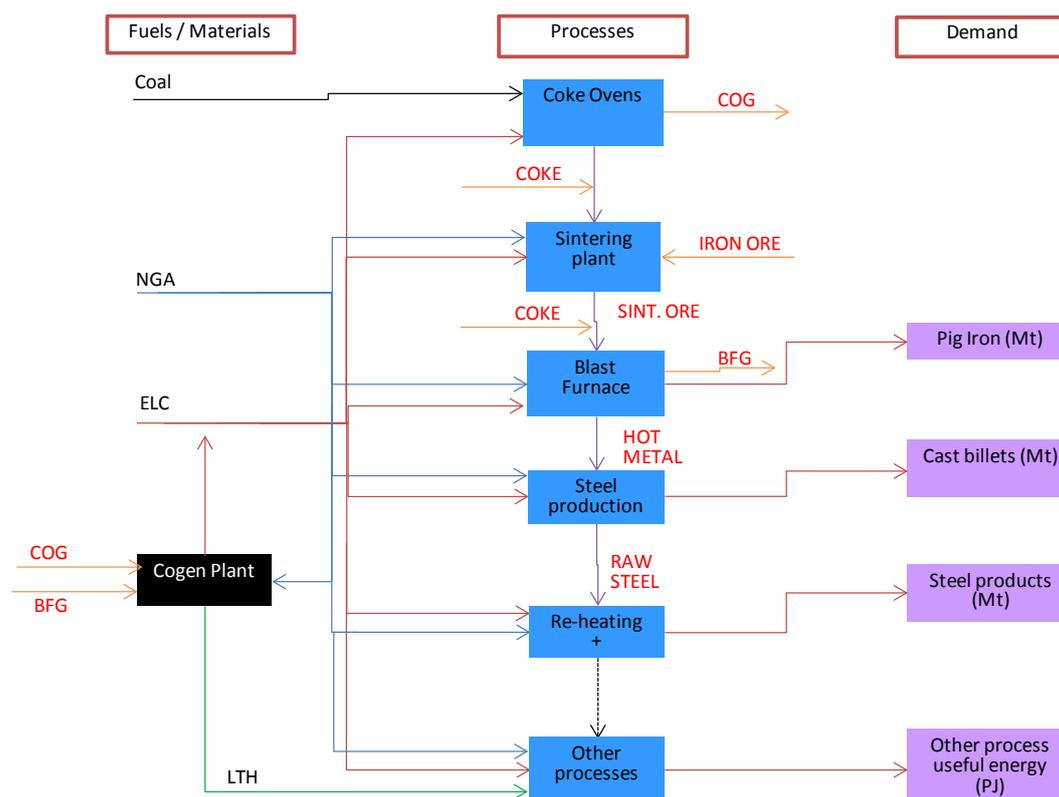


Figure 6. RES for Pakistan Steel Integrated Works

Textiles

This sector is split into three subsectors (as represented by the end use demands):

- Spinning (Yarn production)
- Weaving (Cloth production)
- Finishing (Garment production)

The lack of detailed information for this sector means that processes are characterized in very generic terms – motive power, process heat, and other electric, as shown in Figure 7. Most of the assumptions across these processes are based on the informed expert judgment of MEC (see cells A75:J97). Captive generation is modeled separately (in rows 54-66).

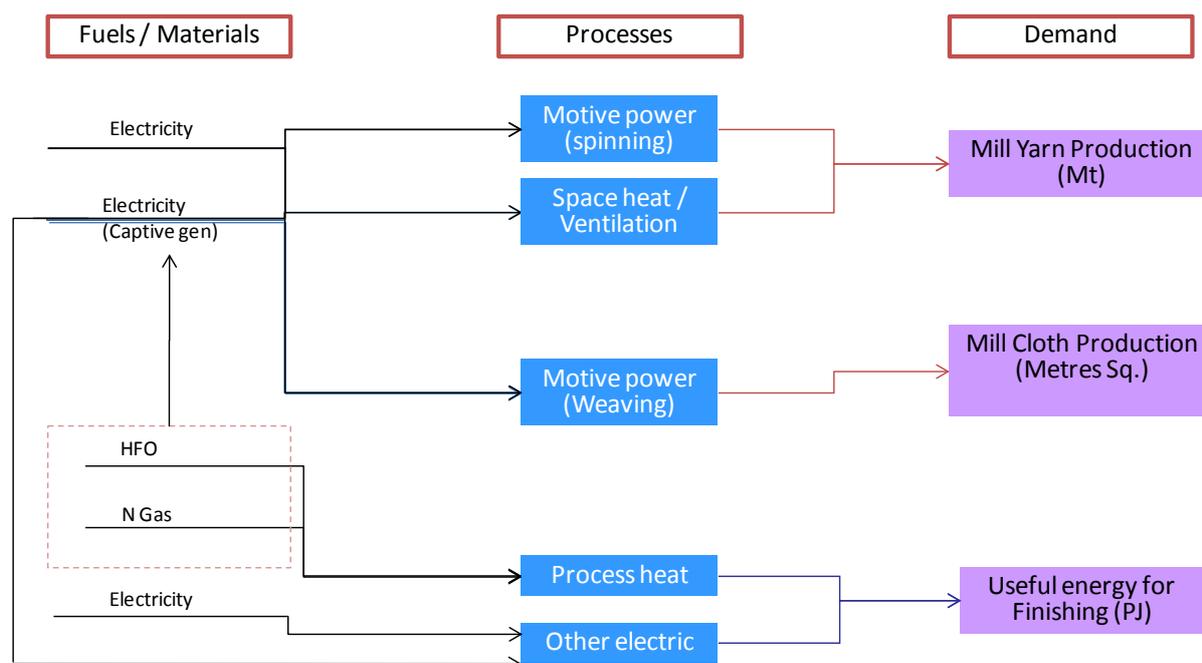


Figure 7. RES for Textile Sector

An important part of this generic process-based approach is that to produce one unit of demand, a specific amount of motive power, process heat, and other electric energy service is required. This requirement is forced in the model through the *Energy services split to meet demand* table (starting row 101), by determining the ratio between the different energy services to meet the demand level in the base year. This is reflected in terms of the Inputs / Output ratio (columns E-F).

Sugar

The sugar sector is very different from other industry sectors, in that it primarily gets all of its energy requirements from bagasse, which is used in cogeneration plants to provide the different sugar production processes with electricity and heat.

As with the textile sector, only generic energy service provision is characterized, and the requirement for each energy service for the production of a tonne of sugar is again defined in table *Energy services split to meet demand* (cells A95:F99).

Two additional processes have been modeled for this sector, based on the molasses produced from the distilling process – ethanol production (*Sugar Ethanol Production Existing*) and fuel grade ethanol production (*Sugar Hydrous Ethanol Production Existing*), which can be exported or used in the domestic transport sector.

The sector RES diagram is shown below, in Figure 8.

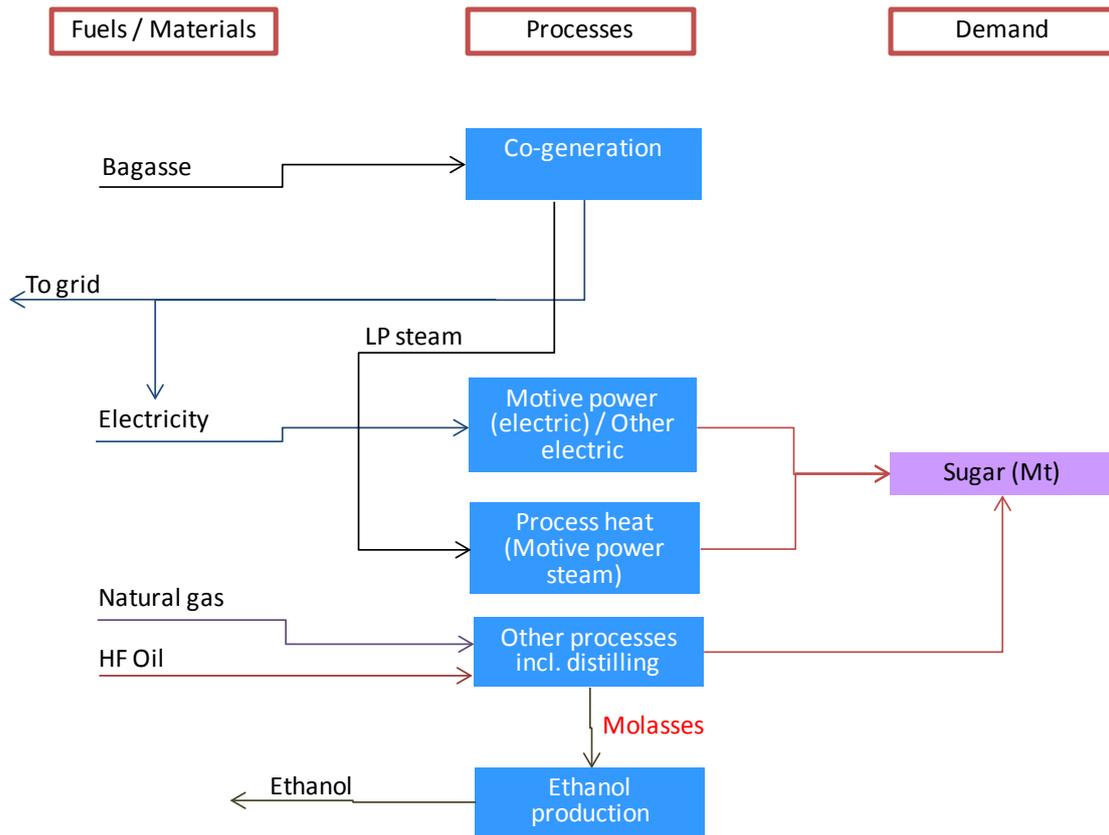


Figure 8. RES for Sugar Sector

Cement

The cement sector worksheet splits production into three types (based on the kiln used for clinker production). This structure was used to take advantage of data provided by the ADB-funded Energy Efficiency assessment undertaken by Hagler-Bailly. Demand is expressed as million tonnes of cement produced (see cell C33). The sector structure is shown in the RES diagram below.

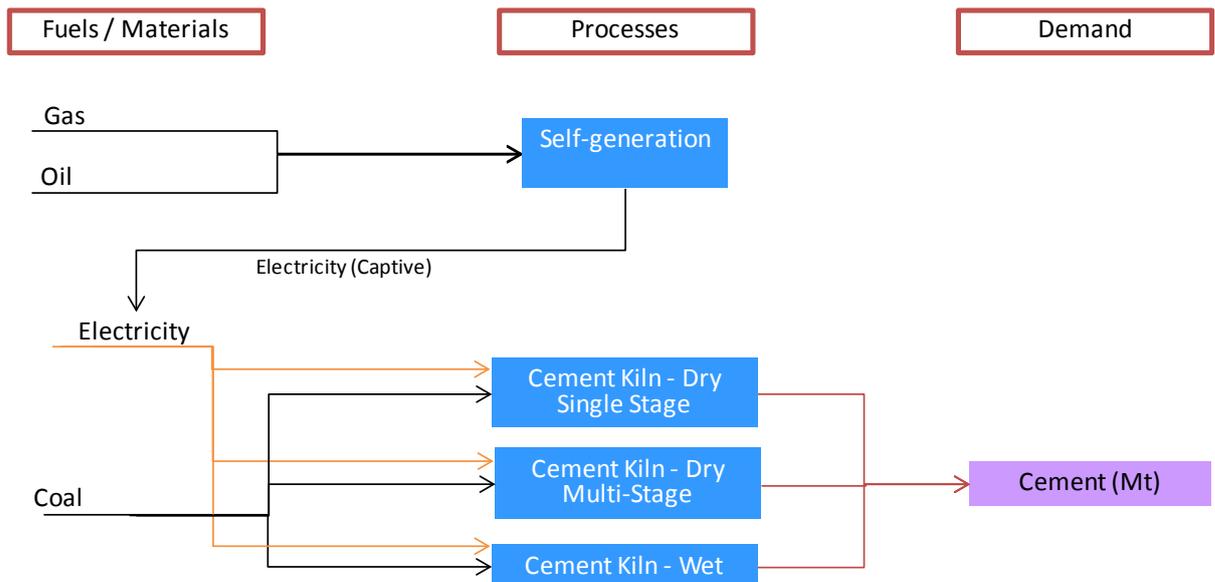


Figure 9. RES for Cement Sector

Approximately half of the electricity used in the sector is produced through captive generation (row 37-49). Because of the input / output structure of the main model load table, an intermediate technology (*ICTELC-E*) was used to create a single electricity commodity, meaning that grid-supplied and captive-generated electricity would not need to be treated as individual commodities.

Each of the cement production processes produces waste heat, the rate of which is captured by the output commodity *INDWHR*. This is modeled because there is a new technology option (in the NewTechs SubRes template) to generate electricity using waste heat.

Brick making

Brick making production is represented by two technologies – bull trench and clamps. Demand is expressed in terms of useful energy consumed. The bull trench technology has an efficiency of 1, against which the other technology efficiency value is relative to. As with the cement sector, this structure was used to take advantage of data provided by the ADB funded Energy Efficiency assessment undertaken by Hagler-Bailly.

Fertilizer

Due to the high levels of natural gas use in this sector, it was considered important to track energy consumption separately; hence, fertilizer is modeled as a separate subsector although has no specific technology level detail.

The sector tracks consumption both of natural gas as a fuel (*INDNGA*) and as a feedstock (*INDNGAR*). This is particularly important when the model is run with sector prices (see scenario *SectorPrices*), as the feedstock gas gets a significant subsidy, while natural gas used as a fuel has an equivalent price to other industry sectors.

Other industry

This sector accounts for the energy consumption not used in the above subsectors. It uses a generic energy service approach as described for the textile sector.

4.4. Residential Households (RSD) by urban and rural

The structure and BY data for the residential sector can be found in the *VT_PAK_RSD* template. The sector is split into urban and rural sectors, with modeling of the following energy services:

- Space Heating
- Water Heating
- Space Cooling (Fans)
- Space Cooling (AC & Coolers)
- Lighting
- Cooking
- Refrigeration
- Miscellaneous Electric
- Other

An urban / rural split is used to represent different characteristics of users groups, in particular access to different energy types and the levels of consumption, with rural groups tending to be lower income (on average). Income classification was considered (when developing the sector structure) but the data does not currently exist to enable such detailed modeling.

A top-down approach is used to disaggregate energy balance estimates across the range of energy services (listed above). The share estimates are shown in rows 39-58 in the main

Residential worksheet. The calculated fuel totals are shown in rows 61-81. The fuel shares values are collated in worksheet *FuelShares*.

Fuel shares

Fuel shares are determined as follows (in worksheet *FuelShares*):

- Start with energy balance totals (row 39).
- Determining the split between rural and urban fuel consumption uses a proxy of households using a specific fuel (rows 45-46). A weighting factor is then used on the household numbers, to reflect the relative consumption levels in a typical household (rows 48-49), from which shares can be derived (rows 53-54). These shares are used in the *Residential* worksheet in rows 14-15.
- End use fuels shares i.e. consumption by fuel type for each energy service can be found in rows 60-82.
 - **Natural gas** – energy service splits into cooking, space and water heating are calculated in worksheet *GasConsumption*. The seasonal consumption profile (provided by gas distribution companies) has been used to derive these shares.
 - **Electricity** – shares are based on analysis undertaken by Hagler Bailly for the ADB SEED project, and can be found in worksheet *HB_EnEff_Analysis*.
 - **Kerosene / LPG** – shares determined based on expert judgment by Planning Team.

Biomass

Biomass estimates are not provided in the Energy Balance. They have been calculated specifically for use in this model, and are important to include due to the significant provision of energy services from this fuel type, particularly in rural areas. The calculation of biomass consumption can be found in worksheet *BiomassEstimates* (a virtual copy of the same named worksheet in the *PakIEM_EnergyBalance-2007* workbook).

Estimates are calculated using information on household energy consumption (from HESS) (see cells A39:C54) and household numbers using biomass fuels (cell A27:C37). The calculated consumption totals can be found in cells B59:C61. The data for use in the model template is collated in columns N-R.

Finally, biomass fuels are split into purchased and free. “Free” means fuel wood that is gathered or sourced locally, and not purchased on the market. The splits between free and purchased can be found in cells O32:Q42.

Technology level data

Once energy consumption has been disaggregated across the different energy services, the individual technologies need to be characterized, for use in the model. The model load table, which holds this information, can be found between rows 83-218. Separate technologies are modeled for each of the subsectors – urban and rural.

The technology level information can be found in worksheet *ModelData*. For further information on sources of information, please refer to the Pak-IEM Final Report: Volume I – Model Design. It is supplemented by data from the US NEMS model (see worksheet *US NEMS Data*) for specific technologies for which Pakistan specific data were difficult to source.

If the analyst wants to change any of the assumptions relating to specific technologies, they should be changed in the *ModelData* worksheet. Some further explanation of the parameters in the data table is provided below:

- *% households* is the % of urban or rural households that own a given appliance, e.g. AC.
- *% stock* is the % of urban or rural households that own a specific type of appliance, e.g. standard or improved AC.
- *Power rating* provides an indication for electrical appliances of how much electricity is used to power it. This has been used as a proxy for differentiating efficiency. The standard appliance takes an efficiency of 1, while a more efficient appliance (i.e. providing the same energy service using a lower power rating) gets an efficiency factor of standard / improved appliance.
- Other energy-using appliances have efficiencies derived from other sources, and are expressed more conventionally as the proportion of useful energy provided per unit of energy input.
- Investment and O&M costs need to be expressed in term of \$/PJ/a for use in the model (columns O and R). Information on how these values have been calculated can be found in the *NewTech* SubRes file.

Within the model load table, many checks are undertaken to assess that final energy consumed by individual technologies sums to the disaggregated energy balance values. These checks are flagged by *V: Sub-total* in column A, with the checking calculations in column P.

4.5. Transportation (TRN) by mode

The transport sector in 2007 is represented in the workbook *VT_PAK_TRN*. Using a bottom-up stock-based approach, as used for the agriculture sector, the energy use in transport is allocated across a set of different vehicle subsectors, providing freight and passenger transport services (expressed as tonne-km or passenger-km). Rail, aviation, and shipping subsectors are not based exclusively on stock data, and are expressed in terms of useful energy, not tonne-km or passenger-km.

Figure 10 shows the stock values (and subsector categories), which can be found at the top of the *Transportation* worksheet (cells C14:C22). The total stock value is compared to the original source data in cell C26. The difference shown (-33.6) reflects the *Other* stock category, which has been omitted from the bottom-up calculations due to lack of information concerning what this includes. In rows 33-40, the stock values are disaggregated by fuel type (as shown below by the pink values). Dual-fueled gasoline / Compressed Natural Gas (CNG) vehicles are categorized as gasoline cars in this table, as essentially, that is what they are with retrofitted CNG.

Transportation Sub-sectors	Demand	Stock 000 vehicles						
Buses	BU	108.4						
Cars	CA	1872.2						
Trucks	TR	182.1						
Vans	VN	148.9						
Two-wheelers	2W	4483.8						
Three-wheelers	3W	79.0						
Taxis	TX	119.1						
Minivans	MV	173.7						
Rail Passenger	RP							
Rail Freight	RF							
Aviation	AV							
Shipping	SH							
	CheckSum	ERR: -33.55						
CNG vehicles (new and converted)		1400.0	82% Petrol vehicles Converted					
	CheckSum							
Stock decomposition by fuel type								
Transportation Sub-sectors	Demand	Gasoline	Diesel	Heavy Oil	Kerosene	Av. Fuel	Natural Gas	Electricity Distributed
Buses	BU		108.37					
Cars	CA	1598.11	274.10					
Trucks	TR		182.13					
Vans	VN		148.88					
Two-wheelers	2W	4483.85						
Three-wheelers	3W	78.99					0.00	
Taxis	TX	113.18	5.98					
Minivans	MV		173.71					
Total		7147.27						
	CheckSum							

Figure 10. Transport Stock Data and Allocation by Primary Fuel Type

For each road vehicle subsector with a stock value, a range of other data values have to be determined, from which a BY fuel consumption value can be derived. These data are listed in Table 7 in **bold type**.

Table 7. Key Data Types to Characterize Road Vehicles

Data requirement by vehicle	Data worksheet	Source
Stock	RT Stock (using NTRC On the road estimates)	NTRC
Efficiency	ENERCON (Act_Eff)	ENERCON
Utilization (km travel per year)	ENERCON (Act_Eff)	ENERCON
Lifetime	PTPS	JICA
Annual maintenance costs	NTRC_VOCs (Vehicle Operating Costs)	NTRC

Using these data, energy consumption values can be calculated by technology type, in the model load table (from row 62 downwards), in column T. Useful demand is shown in column U, and provides the base year demand values. Except for shipping and aviation, demands are expressed in terms of tonne-km or passenger-km. The occupancy factor used to calculate this value in the model can be found in column O, using the attribute *ACTFLO~DEMO*.

Based on these bottom-up estimates, a check has to be made that these estimates match the values reported in the Energy Balance. This calibration is checked in the table labeled *Energy balance checks* (rows 44-59). The table collects all of the bottom-up estimates, sums them (row 58) and then compares the value to the reported Energy Balance value (in row 59). This worksheet shows a very close calibration with only small differences observed (as shown in Figure 11).

		Energy balance checks							
44	End-use Fractional Shares by Demand	Gasoline	Diesel	Heavy Oil	Kerosene	Av. Fuel	Natural Gas	Electricity Distribut	Total
45	Transport - Buses	TBU		49.95					49.95
47	Transport - Cars	TCA	14.17	13.28			49.19		76.64
48	Transport - Trucks	TTR		94.99					94.99
49	Transport - Vans	TVN		13.66					13.66
50	Transport - Two-wheelers	T2W	33.42						33.42
51	Transport - Three-wheelers	T3W	3.14						3.14
52	Transport - Taxis	TTX	2.15	0.40			9.14		11.69
53	Transport - Minivans	TMV		28.69					
54	Transport - Rail Passenger	TRP		5.67				0.04	5.72
55	Transport - Rail Freight	TRF		1.20					1.20
56	Transport - Aviation	TAV				23.25			23.25
57	Transport - Shipping	TSH			0.40				0.40
58		Checksum	52.88	207.84	0.40	0.00	23.25	58.33	0.04
59			ERR: -0.03	ERR: -0.11		ERR: -0.03		ERR: -0.05	

Figure 11. Transport Energy Balance Checks⁴

While the model load table generally uses the same attributes to characterize technologies as seen in other sectors, often the data used is quite different. For example:

- Technology availability (column J) – expressed as km travelled per year, not fraction of the year available as for other sectors.
- Efficiency (column G) is therefore expressed as km travelled per unit of energy used.
- Stock (column P) represents numbers of vehicles.
- Costs (INVCOST/FIXOM/VAROM) are therefore all on a *per vehicle* basis.
- Cap2Act (column N) is the conversion factor to put stock (expressed as 000s vehicles) on to a consistent basis with demand, expressed in million passenger / tonne kms.

An important issue to note is that many of the new technology efficiency factors use BY estimates; **therefore, any changes to BY sector efficiencies may require updates to factors in the SubRes.**

Modeling of the rail sector also follows a stock-based approach, using data from the *Rail* worksheet. Air and shipping modes are modeled in terms of final energy consumption only.

5. Future Technologies

All technology options available for investment in future years are characterized in the *SubRES_NewTechs* template (located in model subfolder *SubRES_TMPL*). The workbook is structured with each sector represented by an individual worksheet, although in the case of industry, subsectors each have a separate worksheet. An index of the different worksheets is provided in the *Legend* worksheet.

Most worksheets have a model load table, characterizing new technology options, and a process definition table. Almost all worksheets have primary data sheets, providing the information for different technologies. The associated primary data sheets and sectors are shown in Table 8.

⁴ The transport diesel total is not the same as the estimate published in the Energy Year Book because agriculture HSD use (partly included in the EYB Transport total) has been accounted for independently. .

Table 8. SubRes Sector Worksheets, and Links to Primary Data

Sector worksheet	Associated primary data sheet
AGR	<i>AGR_Data</i> based on a range of sources
COM	<i>US NEMS COM Data</i>
RSD	<i>RSD ModelData</i> , primarily from Pakistan specific survey information but supplemented (particularly for improved technologies) by US model data, in <i>US NEMS RSD Data</i>
TRN	<i>TRN_NewTechs</i> holds the primary transport technology data, from a range of sources. <i>TRN_VOCs</i> provides supplementary data from NTRC study on costs of vehicle operation.
ELC	<i>ELC_NewTechs</i> , providing a range of sources from which efficiency and cost estimates have been determined. Specific information on hydro plants is found in worksheet <i>ELC_HydroCosts</i> .
ELC_LumpyInv	
ELC_Planned	<i>ELC_PlannedBuild</i> listing the planned new build, and their schedule
SUP	<i>ResourceSupply_Data</i> providing information on future domestic resources and import options
SUP_Planned	<i>Refineries_Data</i> providing information on planned new build and new technology options
IND_ITX	<i>IND_HaglerBaillyEE</i> for energy efficiency retrofit measures (based on ADB SEED analysis by Hagler Bailly)
IND_ISG	<i>IND_SugarCogen1</i> developed by MEC, used to estimate the potential for retrofitting existing cogeneration plants. <i>IND_SugarCogen2</i> contains information on a typical new cogeneration plant, sourced from NEPRA tariff determination information
IND_IFT	
IND_IIS	<i>IND_HaglerBaillyEE</i> for energy efficiency retrofit measures in independent sector (based on ADB SEED analysis by Hagler Bailly)
IND_ICT	<i>IND_CemCogen</i> for data on cement cogeneration, including from waste heat. <i>IND_HaglerBaillyEE</i> for energy efficiency retrofit measures in (based on ADB SEED analysis by Hagler Bailly)
IND_IBK	<i>IND_HaglerBaillyEE</i> for energy efficiency retrofit measures in (based on ADB SEED analysis by Hagler Bailly)
IND_IOT	<i>IND_HaglerBaillyEE</i> for energy efficiency retrofit measures in (based on ADB SEED analysis by Hagler Bailly)

This section of the report describes different parts of the SubRes that are not necessarily obvious to a new analyst, on a sector-by-sector basis. However, it does not attempt to comprehensively describe the template, and assumes that the analyst has a degree of familiarity with the basic template structure.

Resource supply sector (SUP worksheet)

Domestic resources and import / exports options that are available in the base year of the model are characterized in the BY SUP template, as described earlier. This includes information about future year resource availability and cost. The SUP worksheet in the New Techs SubRes includes options that may be available in future years, in particular new import options (see Figure 12 below) not currently available or being exploited.

15	TechDesc	TechName	Comm-IN-A	Comm-IN	Comm-Out
16	Technology Description	Technology Name		Input Commodity	Useful Energy Service
17	V: Units				
18	W: Pipeline				
19	Gas networks New	NETWRKGAS-N		GASRAW GASASS	GASNGA
20					
21	X: Imports-Exports				
22	Domestic Coal Supply - SINDH THAR	MINCOADR			COAD
23	Domestic Gas supply - Tight Gas Reserves	MINGAS-TIGHT-N			GASRAW
24	New Natural gas pipeline from Iran	IMPGAS-IRAN-N			GASIMP
25	New Natural gas pipeline from Iran (Phase 2)	IMPGAS-IRAN2-N			GASIMP
26	New Natural gas pipeline from Central Asia	IMPGAS-CentASIA-N			GASIMP
27	New Liquefied Natural Gas	IMPGASLNG-N			GASLNG
28	New Imported Electricity via CASAREM grid	IMPELCC-N			ELCC
29	New Imported Electricity via future regional grid	IMPELCC2-N			ELCC
30	New Imported Coal for power sector	IMPCOAP-N			COAP
31	New Imported LNG for power sector	IMPGASLNGP-N			GASLNGP
32	New Imported Fertilizer (Dummy)	IMPFERT-N			IMPFRT

Figure 12. New Resource Supply Options in Pak-IEM

The analyst may want to change some of the assumptions relating to the new supply options, as listed and described in Table 9 below. Note that some of the data values are linked to information in worksheet *ResourceSupply_Data*.

Table 9. Key Assumptions for New Resource Supply Options

Assumption	Description
Availability of option	The year when resource is available is controlled by the START date in column P
Infrastructure investment costs	Located in column L, these are expressed in terms of \$million per unit of PJ capacity. Note that these are not discrete investment costs as capacity can be built incrementally.
Commodity costs	Provided for current year, 2030 and 2050. These values are interpolated between the selected years.
Constraint on resource levels	Bounds on the commodity flows ensure that the capacity of these options is restricted (see columns V-AA). In the case of LNG for the power sector, this option is forced in, using a LO bound (cell W31). [Note that the IMPGAS-CentASIA-N pipeline option is eliminated from the Reference Scenario by means of a in <i>REF-ELC/Supply</i> .]
Reserve levels	The domestic resource options (Thar / Tight gas) have cumulative reserve limits (in column AF). The costs of exploiting the tight gas resource need to be developed, based on sector expertise or literature sources.

Due to the introduction of new commodities in the model, a commodity definition table is also included on the worksheet (rows 73-82), in addition to the process definition table seen in every sector worksheet. A number of tracking (or "X") technologies have also been introduced, to capture the use of new commodities in the power generation sector (rows 35-43).

Refining sector (SUP_Planned worksheet)

The assumptions relating to new and planned refinery technologies can be found in this worksheet. Supporting data is located in worksheet *Refineries_Data*. The types of parameters found in the model load table are broadly the same as those found in the SUP

BY template (*Upstream* worksheet). Specific issues that the analyst should be aware of include:

- The new refinery technology (*PREF-New-N*) has a start date of 2017. Due to the planning timeframe, it is unlikely that any refineries will be available before this year beyond those that are already planned. Planned refinery start dates are based on information provided by experts on likely year of commissioning.
- Capacity bounds in column N-O ensure that a maximum build rate of new refineries cannot be exceeded.
- Product slate for planned refineries is provided in *Refineries_Data*. However, adjustment factors in column R allow for non-produced fuels to contribute a small share to future production. The flexibility of the refinery is also adjusted using factors in column S.
- The new and planned refineries have a high input share for domestic crude. This needs to be reduced in future iterations of the model, based on further testing.

Electricity sector

New technologies (*ELC* worksheet)

For new electricity sector options, the majority of the data is sourced from the *ELC_NewTechs* worksheet. This contains a number of alternate datasets that have been compiled to develop estimates relevant to the Pakistan situation. For hydro generation options (rows 51-73), which are modeled by individual (potential) site, data are located in the worksheet *ELC_HydroCosts*. Information includes plant start date, maximum capacity, seasonal availability and investment cost.

Whilst the structure of the model load table is typical of those seen in other sectors, there are a number of issues that the analyst needs to be aware of:

- Column N has the attribute *NCAP_ILED*, which represents the construction time of any new investment. This is important in the calculation of annualized costs, with the investment being made at the start of the construction period i.e. before the plant is operational. The attribute *Start* (column G) therefore relates to when the investment is made. The new capacity is only operational after the construction period e.g. a start date of 2016 with a construction time of 4 years means that the plant will be able to generate electricity in 2020. However, the investment will be made in 2016.
- The attribute *Year* is the year when a specific vintage of the technology is available. Technologies that declare a vintage year are flagged *YES* under the *Vintage* field in the process definition table. Such vintages generally show decreasing costs over time; adjustment factors for the costs can be found in column AK.
- Two other attributes not commonly seen in other sector mode load tables include *DISCRATE* and *PEAK*. *DISCRATE* tends to reflect the cost of capital used for investments, and is used to annualize costs across the lifetime of the technology. *PEAK* is the % of the capacity of a given technology that is able to contribute to supply during the peak demand period.
- There is the potential to increase the investment cost as a result of new transmission lines that would have to be built (above the general costs of additional infrastructure capacity). A transmission line cost increment can be added in column AR,
- Hydro technologies have bounds restricting the capacity to the potential size of that site (column J). All technology groups have build rates restricting new capacity build in a model period (described further in section IV.C.2), located in *REF-ELC/BuildRates*.
- Solar and wind technologies use timeslice specific availability factors. Unlike other technologies, the input energy changes significantly not only by season but by time of day. Data are sourced from US Department of Energy.

- The use of an efficiency factor of 34% for renewable technologies (hydro, wind, solar) is simply to account properly for renewable energy used for electricity in the primary energy balance.
- CCS plants are also included in the new technology set, and could be important for policy analysis exploring lower carbon options. The model load table on technologies for CO₂ storage is shown in Figure 13 below.

104	Storage technologies				~FI_T
105	TechDesc	TechName	Comm-IN	Comm-Out	Start
106	Technology Description	Technology Name	Input Commodity	Output	Start Year
107	Storage option 1	SINKGEO001	PWRCO2		2020
108			SNKPWRCO2		2020
109			SNK001		2020
110	Storage option 2	SINKGEO002	PWRCO2		2020
111			SNKPWRCO2		2020
112			SNK002		2020
113	Storage option 3	SINKGEO003	PWRCO2		2020
114			SNKPWRCO2		2020
115			SNK003		2020
116	Storage option potential 1	MINSINKGEO1		SNK001	2020
117	Storage option potential 2	MINSINKGEO2		SNK002	2020
118	Storage option potential 3	MINSINKGEO3		SNK003	2020

Figure 13. CCS Technology Specification

The approach to modeling storage is as follows – CCS plants not only emit PWRCO₂ (as per all fossil power plants) but also a dummy emission commodity SNKPWRCO₂. A unit of SNKPWRCO₂ is accounted at 90% of a unit of PWRCO₂, to reflect a capture rate of 90%. SNKPWRCO₂ (defined as the primary commodity group) is consumed by the different storage options, as is PWRCO₂. A further commodity SNK001/2/3 is also consumed. This ensures that a cumulative storage capacity cannot be exceeded, based on the technologies describing potential on rows 116-118.

The same amount of PWRCO₂ (in accounting terms) is emitted irrespective of storage; however because some of this commodity is consumed, the net emission will be lower. The CO₂ parameters used to set emission caps – COM_BNDNET and COM_CUMNET – consider the **net** emissions, recognizing this ‘consumed’ PWRCO₂ as stored.

Captive generation technologies are considered separately in the industry subsector worksheets. However, the generic data that has been used to characterize such generation options can be found in cells AA14:AF17.

Planned New Build (ELC Planned worksheet)

This model load table forces electricity plants into the model solution that are planned in the very near term, and hydro plants that are a significant way to completion. Capacity is forced in a specific year using the attribute *NCAP_BND~FX* (see columns U-AB). With no construction time considered, these plants are available once invested in.

Agriculture sector (AGR worksheet)

New technologies for the agriculture sector are modeled relatively simply. All technologies are vintaged, representing generic efficiency improvements over time (relative to base year efficiencies). Efficiency improvement factors in column R are easily adjusted. Investment costs for tractors and tubewells, and efficiency factors for improved tubewells can be found in worksheet *AGR_Data*.

Residential sector (RSD worksheet)

The majority of the data for the residential sector technology options can be found in *RSD ModelData*, with some supplemental information from *US NEMS RSD Data*. The data used in the *RSD ModelData* comes from a range of sources, described in the Pak-IEM Final

Report: Volume I – Model Design. A legend in this worksheet in cells B2:B6 indicates where different values are sourced from. The data are consistent with those used in the BY, with improved technology efficiencies relative to the standard technologies more prevalent in the BY.

The urban and rural subsectors have the same set of technologies, although have been kept distinct to enable separate reporting of subsector results. The modeling of most technologies is relatively straightforward; an exception is heat pumps. Such technologies have dual outputs – heating and cooling, requiring upper output shares (column G) and commodity specific efficiency (CEFF-O, column I), depending on what output the technology is producing.

An important associated scenario file is *REF-DMD*, in which the uptake of more efficient technologies is controlled via different UCs. This is further described in section IV.C.2.

Commercial sector (COM worksheet)

All of the assumptions for the commercial sector technologies come from *US NEMS COM Data* worksheet.

Industry sector

The industry new technologies are subdivided into individual worksheets. There are a number of issues that are relevant across these different subsectors, which are described first:

- **Captive generation** technology assumptions are found in worksheet ELC, as described earlier. Sugar and cement sectors have the opportunity to export electricity to the grid, via technologies *ISGELC-N* (row 29, *IND_ISG* worksheet) and *ICTELC-N* (row 24, *IND_ICT*). There are no constraints on the level of capacity that can be built in these sectors so this should be checked under different scenarios, particularly those that drive up the electricity price of centralized generation options.
- **Retrofit of existing stock.** Existing stock can be retrofitted, to improve energy efficiency of different processes. Any technology that has *retrofit* in the description has the potential for efficiency improvement at a given cost. The potential for retrofit is controlled via user constraints in *REF-DMD/IND_Retrofit*, so that it does not exceed the existing capacity. The data is sourced from the ADB energy efficiency analysis, which can be found in *IND_HaglerBaillyEE*.

The structure of the sector is as described in the Industry BY template. Therefore, only those issues that require fuller description are listed in Table 10 below.

Table 10. Industry New Technology Issues by Subsector

Subsector (worksheet)	Specific issues
Textiles (IND_ITX)	<ul style="list-style-type: none"> • Efficiency improvements can be found in column S, and are relative to BY efficiencies (column R). These need to be updated if changes to estimates are made in the BY template. • Cost estimates need to be further developed for new (not retrofit) technologies. Currently, they are at least double the cost of retrofit options.

Sugar (IND_ISG)	<ul style="list-style-type: none"> Efficiency improvements can be found in column S, and are relative to BY efficiencies (column R). These need to be updated if changes to estimates are made in the BY template. Cost estimates need to be further developed for new (not retrofit) technologies excluding CHP. These values are shaded orange. The technology <i>ISGELC-N</i> (row 29) allows for production of electricity from this sector to be sold to the main grid.
Fertilizer (IND_IPT)	<ul style="list-style-type: none"> The technology <i>IFTPIMP-N</i> (row 13) allows for imported fertilizer as an alternative to domestic production. This is chosen if gas prices increase significantly. The costs of the import are on the import process <i>IMPFERT-N</i>, in worksheet <i>SUP</i>.
Iron and Steel (IND_IIS)	<ul style="list-style-type: none"> Efficiency improvements can be found in column P, and are relative to BY efficiencies (column R-S). These need to be updated if changes to estimates are made in the BY template. Cost estimates are uncertain for new technologies (see orange shaded cells) are generally factored on retrofit and new technology estimates.
Cement (IND_ICT)	<ul style="list-style-type: none"> The technology <i>ICTELC-N</i> (row 24) allows for production of electricity from this sector to be sold to the main grid.
Bricks (IND_IBK)	<ul style="list-style-type: none"> Cost estimates are factored on retrofit cost estimates.
Other (IND_IOT)	<ul style="list-style-type: none"> Efficiency improvements can be found in column S, and are relative to BY efficiencies (column R). These need to be updated if changes to estimates are made in the BY template. Cost estimates need to be further developed for new (not retrofit) technologies.

Transport sector (TRN worksheet)

There are a range of new technology options available for different road vehicles, including improved conventional and alternative technologies. The uptake of many of the technologies is controlled through the use of UCs, found in *REF-DMD/TRN_TechShare*.

Most of the data values used in the model are in worksheet *TRN_NewTechs*. The data is arranged in the worksheet so that collated data (which the model load table links to) is in columns A-V. Source data are to the right of column V. Due to the linked nature of the template, it is preferable if changes to the assumptions are made in the data worksheet. All these sources are described in the Pak-IEM Final Report: Volume I – Model Design.

The structure of the model load table is similar to that seen in the BY template. It does have two additional attributes required for the modeling of electric cars:

- Timeslice (TIMES parameter name is *PRC_TSL*) – denotes the charging periods; as these have been defined as night time storage devices, the designated periods are WN, SN and IN, and
- NSTTS* – sets the percentage charging permitted during the designated charging periods.

The technology, in the process definition sheet, is then defined as a NST (night storage device) – see row 201. Electric vehicles do not necessarily have to be designated night storage devices i.e. charge at night, used in the day. They can be modeled much more flexibly, charging at anytime.

Two additional parameters not used in this instance but which could be potentially useful in the future include:

- FLO_MARK is the share of the commodity output that can be provided by this technology; in the Pak-IEM example, the commodity output for cars on which to apply this parameter would be TCA.
- AFAC is the commodity-specific availability factor. If a vehicle technology produces two outputs e.g. long distance and short distance travel, the availability of the technology to produce either output could be restricted – for electric vehicles, long distance travel could be restricted to a very low AF due to battery range issues.

For rail technologies, generic efficiency improvement factors are provided in column W, and are relative to BY factors, in column V.

6. Demand Projections

Useful energy demand projections for Pak-IEM are developed in the master demand projection workbook *ScenDem_DEM_PIEMRef*. This workbook is designed such that after any changes or updates are made to the Reference Scenario projection (REF), the medium and low (or high if added) demand scenario files can be generated from the master file – as will be explained below. The Pak-IEM demand projection workbook develops the future demand for energy services using appropriate demand drivers (e.g., GDP, population, energy intensity, etc.). The drivers for each energy service demand are those that most directly impact its potential growth, and the relationship (e.g., elasticity) between each driver and the associated energy service demand must also be established. Finally, any external factors affecting the demand growth (e.g., autonomous energy improvement) also need to be determined. The basis of the demand projections is described in more detail in the Pak-IEM Final Report: Volume I – Model Design.

The demand projection workbook is organized according to the following worksheets.

- **Legend:** provides a color-coded overview of the workbook.
- **Driver:** contains the table of demand drivers that are uploaded into the model, these drivers are factors that get applied to the BY energy service demands to calculate the energy service demand projections. The sheet is populated for a particular scenario according to the *GDP* sheet [A2] selection.
- **Population:** contains population projections from the National Population Policy Report -2010 and household size projections from PSLM and HEIS that are used to make projections of the number of urban and rural households.
- **GDP:** contains the GDP projections according to the major commodity production sectors. Government projections by service sector are used to generate sectoral GDP growth rates for the reference case, and expert judgment has been used to develop the medium and low growth cases. This sheet contains a selection box in cell A2 that is used to populate the *Driver* sheet with the Reference (REF), Medium (MED), or Low (LOW) projection.
- **GDP Plots:** collects data from the *GDP* sheet to produce charts of the GDP projections.
- **WEO Data:** contains World Economic Outlook statistics and near-term projections for Pakistan from the International Monetary Fund. This data was used as a benchmark for the GDP projections.
- **EnergyBalance:** contains energy balance information, sourced from EYB2007, which was used to support calculations in other sheets.
- **WorldBank_DevelopmentIndicators:** contains World Bank Development Indicator data that was also used as a benchmark against the GDP, population and other projections used in the workbook.
- **Residential:** contains the main calculations for residential sector demand drivers and it described in detail below.
- **Residential Charts:** contains charts of household electricity consumers.

- **Industry:** calculations sheet for industry sector drivers and is described in detail below.
- **Commercial:** contains the calculations for commercial sector demand drivers and is described in detail below.
- **Agriculture:** contains the calculations sheet for agriculture sector drivers and is described in detail below.
- **Transport:** contains the calculations sheet for transport sector drivers and is described in detail below.
- **Transport Analysis:** contains charts of passenger and freight demand projections.
- **BiomassEstimates:** contains calculation of base year biomass estimates, to help inform the residential sector demand projections.
- **BiomassDataReview** contains data sources used to calculate base year biomass estimates (see *RSD* base year workbook).
- **UETT Survey:** contains the results of the UETT survey of electricity use in a sample of Punjab households. This data is used to understand electricity consumption for different residential energy services.
- **HESS:** contains the core HESS assumptions, and was particularly useful in understanding the relative levels of household energy consumption (between urban / rural and income groups).
- **WRI_RSD Energy:** contains comparative country estimates of residential per capita energy use (sourced from World Resources Institute).
- **WRI_GDP per capita:** This sheet contains comparative country estimates of GDP per capita (sourced from World Resources Institute).
- **WRI_Energy V GDP:** contains a regression analysis, comparing GDP per capita against energy use per capita. This analysis provides one of the main drivers for increased household energy consumption as GDP increases.
- **Conversion:** Energy conversion factors.
- **Currency:** Currency exchange rates and deflators.
- **CONST:** Additional conversion factors.

Residential

The residential sector energy service demands are developed for the following end-use applications for both urban and rural households. All demands, listed below, are in units of PJ.

- Space Heating
- Water Heating
- Space Cooling (Fans and Coolers)
- Space Cooling (AC)
- Lighting
- Cooking
- Refrigeration
- Miscellaneous Electric
- Other

The workbook is organized in blocks to handle various aspects of preparing the residential projections as discussed below. To determine useful energy consumption at the end-use application level for both urban and rural households, the energy balance data was disaggregated – first by fuel type and then by end-use application – so that typical device efficiencies could be estimated and applied to calculate useful energy demands.

The projections below are based on final energy use, which is what is available from the international literature for developing countries, as developed by World Resources Institute (WRI) and others. The data mentioned above in Col Q comes from a WRI report, which provides energy use per capita and GDP per capita. That data was used to develop a relationship between energy use per capita and GDP per capita, which is shown on the *WRI_Energy V GDP* sheet.

- Calculation of the number of electricity customers (households) for both urban and rural areas takes place in rows 61-77. For urban areas, the percentage is projected to go from 98% in 2007 to 100% in 2012. For rural areas, the number of connected households starts at the 2007 level and grows in proportion to the growth in rural population with additions for village electrification and migration from un-electrified areas to electrified villages. Rural households start at 81% electrified in 2007 to 91% electrified in 2030.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
61						Electricity Customers, Millions											
62		Key Indicators		2007	2009	2012	2015	2018	2021	2024	2027	2030	2033	2036	2039	2042	2045
63		Connected Households		14.4	22.6	24.6	26.6	28.7	31.8	33.3	35.8	38.4	41.1	43.9	46.9	50.2	53.6
64		Annual growth rate			16%	3%	3%	3%	3%	2%	2%	2%	2%	2%	2%	2%	2%
65		Urban Households		8.3	9.2	10.7	12.2	13.7	15.3	17.0	18.8	20.8	23.0	25.1	27.3	29.8	32.5
66		% connected to grid		98%	99%	100%											
67		Urban Household Consumers		8.1	9.2	10.7	12.2	13.7	15.3	17.0	18.8	20.8	23.0	25.1	27.3	29.8	32.5
68																	
69		Rural Households		15.1	15.7	16.1	16.5	17.0	17.5	18.1	18.7	19.3	19.9	20.8	21.7	22.6	23.5
70		Rural Household current ELC connected		12.2	12.3	12.4	12.6	12.9	13.2	13.5	13.9	14.2	14.5	15.0	15.5	16.0	16.5
71		Village Electrification		0.7	0.9	1.2	1.5	1.9	2.2	2.6	2.9	3.2	3.4	3.6	3.8	4.1	4.3
72		Rural Electrification rate			10%	9%	8%	7%	6%	5%	4%	3%	2%	2%	2%	2%	2%
73		Migration to Electrified villages				10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
74		Rural Household Consumers		12.2	13.3	13.9	14.4	15.0	15.6	16.3	17.0	17.6	18.1	18.6	19.6	20.3	21.1
75		Rural Electrification Ratio		81%	85%	85%	87%	88%	89%	90%	91%	91%	91%	90%	90%	90%	90%
76		Overall Electrification Ratio		87%	90%	92%	93%	94%	94%	95%	95%	96%	96%	96%	96%	96%	96%
77																	

- For each household end-use, the energy projection is made based on the per capita energy intensity increase indicated in Col Q. This can be seen on Row 88 for Urban Space Heating. The household energy projection is multiplied by the urban household population to get total energy demand, and the ratio of this projected energy use to the base year value is the demand driver – as shown for this example on Row 91. Two significant drivers to energy demand are the percentage of households with air conditioners and the percentage of households with refrigerators, and the annual growth rate of these two major appliances is an important user input. This process is repeated for each end-use application, separately for the urban [rows 79-123] and rural [rows 126-171] households. The resulting demand drivers are passed to the *Drivers* sheet.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
79		Households Types - Urban															
80		Households with grid electricity		8.08	9.15	10.72	12.19	13.88	15.35	16.98	18.78	20.77	22.98	25.07	27.34	29.83	32.54
81		Households with air conditioning	10.00%	0.81	0.91	1.08	1.29	1.53	1.83	2.18	2.59	3.09	3.68	4.26	4.93	5.70	6.60
82		Annual growth in HH with air conditioning		6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%
83		% of Urban HH with air conditioning		10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
84		Households with refrigerators	13.85%	1.12	1.26	1.58	1.79	2.13	2.53	3.01	3.59	4.28	5.09	5.90	6.83	7.90	9.15
85		Annual growth in HH with refrigerators		6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%
86		% of Urban HH with refrigerators		7%	8%	9%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
87																	
88	RUH	Space Heating Energy use per HH (MJ)		1.887	1.950	2.044	2.138	2.232	2.327	2.421	2.515	2.609	2.703	2.798	2.892	2.986	3.080
89		Change in intensity															63%
90		Space Heating Final Energy (PJ)		15.63	19.02	21.90	26.07	30.54	36.71	41.09	47.22	54.20	62.13	70.12	79.06	89.06	100.25
91		Space Heating ESD (Driver)		1.00	1.15	1.40	1.67	1.95	2.28	2.63	3.02	3.47	3.97	4.49	5.06	5.70	6.41
92	RUW	Water Heating Energy use per HH (MJ)		6.441	6.855	6.977	7.299	7.620	7.941	8.263	8.584	8.906	9.227	9.549	9.870	10.192	10.514
93		Change in intensity															63%
94		Water Heating Final Energy (PJ)		53.35	61.52	74.75	89.00	104.24	121.89	140.25	161.18	184.59	212.07	239.35	269.86	303.59	342.16
95		Water Heating ESD (Driver)		1.00	1.15	1.40	1.67	1.95	2.28	2.63	3.02	3.47	3.97	4.49	5.06	5.70	6.41
96	RUC	Cooling (non-AC) Energy use per HH (MJ)		2.280	2.356	2.470	2.584	2.698	2.812	2.925	3.039	3.153	3.267	3.381	3.495	3.609	3.722
97		Change in intensity															63%
98		Cooling (non-AC) Final Energy (PJ)		18.43	21.55	25.47	31.51	38.91	43.16	49.66	57.07	65.50	75.09	84.74	95.65	107.63	121.14
99		Cooling (non-AC) ESD (Driver)		1.00	1.17	1.44	1.71	2.00	2.34	2.69	3.10	3.55	4.07	4.60	5.18	5.84	6.57
100	RUA	AC Energy use per HH (MJ)		7.312	7.799	8.529	9.259	9.990	10.720	11.450	12.180	12.910	13.640	14.370	15.100	15.830	16.560
101		Change in intensity															205%
102		AC Final Energy (PJ)		5.91	7.08	9.23	11.93	15.33	19.59	24.92	31.57	39.66	50.16	61.17	74.41	90.31	109.36
103		AC ESD (Driver)		1.00	1.20	1.56	2.02	2.59	3.31	4.22	5.34	6.74	8.49	10.35	12.59	15.28	18.50
104	RUL	Lighting Energy use per HH (MJ)		2.020	2.087	2.198	2.289	2.390	2.491	2.592	2.693	2.793	2.894	2.995	3.096	3.197	3.298
105		Change in intensity															63%
106		Lighting Final Energy (PJ)		15.33	19.18	23.45	27.92	32.70	38.23	43.99	50.56	58.03	66.52	75.07	84.65	95.35	107.32
107		Lighting ESD (Driver)		1.00	1.17	1.44	1.71	2.00	2.34	2.69	3.10	3.55	4.07	4.60	5.18	5.84	6.57
108	RUK	Cooking Energy use per HH (MJ)		23.975	24.773	25.959	27.166	28.393	29.650	30.937	31.954	33.151	34.347	35.544	36.741	37.938	39.135
109		Change in intensity															63%
110		Cooking Final Energy (PJ)		199.60	228.99	278.28	331.28	388.01	453.71	522.10	599.98	688.60	789.41	890.92	1,004.51	1,131.56	1,273.63
111		Cooking ESD (Driver)		1.00	1.15	1.40	1.67	1.95	2.28	2.63	3.02	3.47	3.97	4.49	5.06	5.70	6.41
112	RUR	Refrigeration Energy use per HH (MJ)		1.010	1.043	1.094	1.144	1.194	1.245	1.295	1.346	1.396	1.446	1.497	1.547	1.598	1.648
113		Change in intensity															63%
114		Refrigeration Final Energy (PJ)		1.13	1.31	1.64	2.04	2.54	3.15	3.90	4.83	5.97	7.37	8.92	10.56	12.62	15.67
115		Refrigeration ESD (Driver)		1.00	1.16	1.45	1.81	2.25	2.79	3.45	4.27	5.28	6.52	7.81	9.34	11.17	13.34
116	RUM	Misc. Elec. Energy use per HH (MJ)		987	1,020	1,069	1,116	1,167	1,217	1,265	1,315	1,364	1,414	1,463	1,512	1,561	1,611
117		Change in intensity															63%
118		Misc. Elec. Final Energy (PJ)		7.98	9.33	11.45	13.63	16.97	18.67	21.49	24.69	28.34	32.49	36.67	41.34	46.57	52.42
119		Misc. Elec. ESD (Driver)		1.00	1.17	1.44	1.71	2.00	2.34	2.69	3.10	3.55	4.07	4.60	5.18	5.84	6.57
120	RUO	Other Energy use per HH (MJ)		470	486	509	533	556	580	603	627	650	674	697	720	744	767

- Energy balance data is apportioned between urban and rural households based on ESMAP data on percentages of households consuming various fuels [rows 176-196], which is shown starting in cell T84. The relative energy use for urban and rural households is taken from HESS data to calculate the fuel shares between urban and rural households, which when multiplied by the energy balance data gives the urban and rural fuel use.

	A	B	C	D	E	F	G	H	I	J	K	L	M
175		Sourced from EB spreadsheet											
176		BY Final Energy Consumption - Residential (PJ)		Kerosene	LPG	Coal	Natural Gas	Electricity	Woodfuel	Dung	Agr. Residues	Solar	Diesel
177				4.8	19.4	0.02	191.9	120.0	470.1	108.0	74.9		
178													
179													
180													
181		Number of households (millions) using each energy carrier (2001 shares)		Kerosene	LPG	Coal	Natural Gas	Electricity	Woodfuel	Dung	Agr. Residues	Solar	Diesel
182													
183		Urban		1.16	0.67		5.14	8.08	2.07	0.73	0.43		
184		Rural		7.41	1.22		0.50	12.22	10.74	5.90	5.14		
185													
186		Relative consumption weighting		Urban	0.82	1.13		1.77	1.46	0.74	1.07	1.06	
187				Rural	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
188					8.36	1.98		9.61	24.01				
189													
190		Fuel shares - Urban / Rural											
191		Urban		0.11	0.38	0.00	0.95	0.49	0.13	0.12	0.08		
192		Rural		0.89	0.62	1.00	0.05	0.51	0.87	0.88	0.92		
193													
194		Fuel totals											
195		Urban		0.6	7.4		181.9	58.9	58.8	12.6	6.1		
196		Rural		4.3	12.0	0.02	10.0	61.1	411.3	95.4	68.8		

- End-use fuel shares by fuel type are calculated [rows 198-220], and are informed largely by HESS data with the exception of biomass consumption estimates that are taken from *BiomassEstimates* sheet, which draws data from the *BiomassDataReview* sheet.

198	End use Fuel Shares by FUEL TYPE												
199	Urban Households	Total	Kerosene	LPG	Coal	Natural Gas	Electricity	Woodfuel	Dung	Agr. Residues	Solar	Diesel	
200	Urban Space Heating	13.2				0.06		0.05					
201	Urban Water Heating	44.5				0.20		0.15					
202	Urban Space Cooling (Fans and Coolers)	18.4					0.31						
203	Urban Space Cooling (AC)	5.9					0.10						
204	Urban Lighting	17.2	0.54	0.02			0.28						
205	Urban Cooking	207.4	0.42	0.98		0.75		0.78	0.95	1.00			
206	Urban Refrigeration	8.2					0.14						
207	Urban Miscellaneous Electric	8.0					0.14						
208	Urban Other	3.7	0.04	0.00		0.00	0.03	0.02	0.05	0.00			
209													
210													
211	Rural Households	Total	Kerosene	LPG	Coal	Natural Gas	Electricity	Woodfuel	Dung	Agr. Residues	Solar	Diesel	
212	Rural Space Heating	32.2				0.02		0.08					
213	Rural Water Heating	36.5				0.00		0.09					
214	Rural Space Cooling (Fans and Coolers)	21.2					0.35						
215	Rural Space Cooling (AC)	1.9					0.03						
216	Rural Lighting	30.1	0.93	0.02			0.42						
217	Rural Cooking	520.3	0.04	0.98		0.97		0.83	0.94	1.00			
218	Rural Refrigeration	3.5					0.06						
219	Rural Miscellaneous Electric	6.5					0.11						
220	Rural Other	10.6	0.03	0.00	1.00	0.00	0.04	0.01	0.06	0.00			

- Energy consumption shares by end-use application [rows 224-247] are calculated based on the fuel shares and energy consumption totals by end-use application, which are calculated in cells C200:220.

	A	B	C	D	E	F	G	H	I	J	K	L	M
224		End use Fuel Shares by END USE TYPE [conditional formatting used to identify key fuels by end use]											
225		Urban Households	Total	Kerosene	LPG	Coal	Natural Gas	Electricity	Woodfuel	Dung	Agr. Residues	Solar	Diesel
226		Urban Space Heating	13.2				0.79		0.21				
227		Urban Water Heating	44.5				0.81		0.19				
228		Urban Space Cooling (Fans and Coolers)	18.4					1.00					
229		Urban Space Cooling (AC)	5.9					1.00					
230		Urban Lighting	17.2	0.02	0.01			0.97					
231		Urban Cooking	207.4	0.00	0.04		0.65		0.22	0.06	0.03		
232		Urban Refrigeration	8.2					1.00					
233		Urban Miscellaneous Electric	8.0					1.00					
234		Urban Other	3.7	0.01	0.00		0.00	0.47	0.35	0.17	0.00		
235		Total	326.4										
236													
237		Rural households	Total	Kerosene	LPG	Coal	Natural Gas	Electricity	Woodfuel	Dung	Agr. Residues	Solar	Diesel
238		Rural Space Heating	32.2				0.01		0.99				
239		Rural Water Heating	36.5				0.00		1.00				
240		Rural Space Cooling (Fans and Coolers)	21.2					1.00					
241		Rural Space Cooling (AC)	1.9					1.00					
242		Rural Lighting	30.1	0.13	0.01			0.86					
243		Rural Cooking	520.3	0.00	0.02		0.02		0.65	0.17	0.13		
244		Rural Refrigeration	3.5					1.00					
245		Rural Miscellaneous Electric	6.5					1.00					
246		Rural Other	10.6	0.01	0.00	0.002	0.00	0.20	0.24	0.54	0.00		
247		Total	662.8										

- Base year efficiency value for typical devices by application and fuel type are entered in rows 249-271 and used to calculate useful energy consumption by end-use and fuel type [rows 274-297].

	A	B	C	D	E	F	G	H	I	J	K	L	M
248		Base Year Efficiencies [Used to derive BY useful energy demand]											
249		Urban Households		Kerosene	LPG	Coal	Natural Gas	Electricity	Woodfuel	Dung	Agr. Residues	Solar	Diesel
251		Urban Space Heating					0.60		0.15				
252		Urban Water Heating					0.60		0.15				
253		Urban Space Cooling (Fans and Coolers)						0.70					
254		Urban Space Cooling (AC)						0.80					
255		Urban Lighting		0.30	0.50			0.70					
256		Urban Cooking		0.40	0.55		0.55		0.15	0.15	0.15		
257		Urban Refrigeration						0.80					
258		Urban Miscellaneous Electric						0.70					
259		Urban Other		0.30	0.50		0.55	0.70	0.15	0.15	0.15		
260													
261													
262		Rural households		Kerosene	LPG	Coal	Natural Gas	Electricity	Woodfuel	Dung	Agr. Residues	Solar	Diesel
263		Rural Space Heating					0.60		0.15				
264		Rural Water Heating					0.60		0.15				
265		Rural Space Cooling (Fans and Coolers)						0.70					
266		Rural Space Cooling (AC)						0.80					
267		Rural Lighting		0.30	0.50			0.70					
268		Rural Cooking		0.40	0.55		0.55		0.15	0.15	0.15		
269		Rural Refrigeration						0.80					
270		Rural Miscellaneous Electric						0.70					
271		Rural Other		0.30	0.50	0.25	0.55	0.70	0.15	0.15	0.15		
272													

- The useful energy values [C276-C296] are used as the seed values to the demand projections [rows 36-57].

	A	B	C	D	E	F	G	H	I	J	K	L	M
274		Useful Energy											
275		Urban Households	Useful Energy (PJ)	Kerosene	LPG	Coal	Natural Gas	Electricity	Woodfuel	Dung	Agr. Residues	Solar	Diesel
276		Urban Space Heating	6.7				6.25		0.42				
277		Urban Water Heating	22.8				21.54		1.29				
278		Urban Space Cooling (Fans and Coolers)	12.9					12.90					
279		Urban Space Cooling (AC)	4.7					4.73					
280		Urban Lighting	11.9	0.09	0.08			11.70					
281		Urban Cooking	88.3	0.09	4.00		74.58		6.92	1.80	0.92		
282		Urban Refrigeration	6.5					6.53					
283		Urban Miscellaneous Electric	5.6					5.58					
284		Urban Other	1.5	0.01	0.00		0.00	1.20	0.19	0.10	0.00		
285		Total	160.9										
286													
287		Rural households	Useful Energy (PJ)	Kerosene	LPG	Coal	Natural Gas	Electricity	Woodfuel	Dung	Agr. Residues	Solar	Diesel
288		Rural Space Heating	4.9				0.15		4.80				
289		Rural Water Heating	5.5				0.01		5.48				
290		Rural Space Cooling (Fans and Coolers)	14.8					14.83					
291		Rural Space Cooling (AC)	1.6					1.56					
292		Rural Lighting	19.4	1.20	0.13			18.09					
293		Rural Cooking	86.7	0.06	6.45		5.33		51.04	13.44	10.32		
294		Rural Refrigeration	2.8					2.77					
295		Rural Miscellaneous Electric	4.5					4.55					
296		Rural Other	2.8	0.04	0.00	0.00	0.00	1.50	0.38	0.86	0.00		
297		Total	143.0										

- Household energy intensity values (final energy) are calculated and aggregated per end-use application [rows 300-322, column O]. These values are linked to the seed values for the household energy projections [D88-168].

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
299															
300		Household Energy Intensity Factors - Urban Households - MJ/HH [CALCULATED FROM ABOVE DATA]													
301		Urban Households		Kerosene	LPG	Coal	Natural Gas	Electricity	Woodfuel	Dung	Agr. Residues	Solar	Diesel		Weighted totals
302		Urban Space Heating					2,030		1,357						1,887
303		Urban Water Heating					6,989		4,150						6,441
304		Urban Space Cooling (Fans and Coolers)						2,280							2,280
305		Urban Space Cooling (AC)						7,312							7,312
306		Urban Lighting		258	233			2,068							2,020
307		Urban Cooking		198	10,841				22,277	16,437	14,233				23,975
308		Urban Refrigeration					26,404								1,010
309		Urban Miscellaneous Electric						987							987
310		Urban Other		19	0		0	212	624	870	0				470
311															
312															
313		Rural households		Kerosene	LPG	Coal	Natural Gas	Electricity	Woodfuel	Dung	Agr. Residues	Solar	Diesel		Weighted totals
314		Rural Space Heating					409		2,900						2,961
315		Rural Water Heating					49		3,401						3,399
316		Rural Space Cooling (Fans and Coolers)						1,733							1,733
317		Rural Space Cooling (AC)						159							159
318		Rural Lighting		530	200			2,115							1,950
319		Rural Cooking		72	9,588				31,699	15,196	13,386				29,698
320		Rural Refrigeration					19,436								204
321		Rural Miscellaneous Electric						532							532
322		Rural Other		19	0	20	0	175	234	974	0				622
323															

- Household energy intensity factors from the HESS medium income category [rows 326-348] are shown for comparison purposes only. These were not used.
- Aggregation of the subsector energy demand projections are collected in rows 22 to - 59.

Industry

The industry sector demand projections are developed according to the following categories. Most of the demands are expressed in activity units, such as million tons (Mt), while a few are expressed in PJ, and one is expressed in billion square meters (Bm2).

Sub-sector demand category	Units
Textiles Yarn production	Mt
Textiles Cloth production	Bm2
Textiles Garment production	PJ
Sugar production	Mt
Cement production	Mt
Iron and Steel Integrated Pig Iron	Mt
Iron and Steel Integrated Cast Billet	Mt
Iron and Steel Integrated Steel Products	Mt
Iron and Steel Integrated Other Processes	PJ
Iron and Steel Independent Billets (Independent)	Mt
Iron and Steel Independent Construction steel	Mt
Iron and Steel Independent Other (Independent)	PJ
Brick kilns	PJ
Fertilizer production	Mt
Other industry	PJ

- Industrial component of GDP growth (row 23) is the principal driver for many, but not all of the sub-sectors. Because of the diversity of the various industry sub-sectors,

each uses a slightly different approach to the demand projection, which is described below.

- Demand drivers are calculated in rows 68 to 82 and are linked to the *Drivers* sheet.
- Actual demand projection are calculated from the useful energy demand values for EBY2007 [rows 3-18], which are copied to Col-D from the *VT_PAK_IND* template.
- Aggregations of the sub-sector energy demand projections are collected in rows 3 to 18.

The process of developing the various subsector demand projection is described below for each industry.

Textiles

The textile sub-sector energy service demand is **not** developed using the industry sector GDP growth as the driver. Because of the importance of this sub-sector and because of the international competitive factors that strongly influence its growth, it was decided to develop independent growth factors for each segment of the textile sub-sector based on data from the *2010 Economic Survey*. Those growth factors are found in rows 26 thru 39 and are given in REF, MED, and LOW categories that are linked to the demand scenario selection box in cell A2 of the *GDP* sheet. The growth rates for each textile industry segment and demand scenario were developed based on near-term issues as well as expected long-term trends.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
24																		
25		Textiles (Not linked to Industry GDP)																
26		Growth factor - Textiles Yarn production		1.00	1.03	1.14	1.32	1.57	1.87	2.23	2.65	3.16	3.77	4.48	5.34	6.36	7.58	
27				REF	1.30%	3.50%	5.00%	6.00%	6.00%	6.00%	6.00%	6.00%	6.00%	6.00%	6.00%	6.00%	6.00%	
28				MED	1.86%	2.00%	3.00%	4.00%	4.00%	4.00%	4.00%	4.00%	4.00%	4.00%	4.00%	4.00%	4.00%	
29				LOW	1.30%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	1.50%	
30																		
31		Growth factor - Textiles Cloth production		1.00	1.10	1.31	1.66	2.14	2.78	3.59	4.53	5.65	6.99	8.69	10.64	11.88	13.67	
32				REF	9.00%	6.00%	8.00%	9.00%	9.00%	9.00%	8.00%	7.00%	7.00%	6.00%	6.00%	6.00%	6.00%	
33				MED	5.00%	5.50%	6.00%	6.00%	7.50%	7.50%	6.00%	5.00%	4.00%	4.00%	4.00%	4.00%	4.00%	
34				LOW	6.00%	6.00%	6.00%	6.00%	6.00%	6.00%	6.00%	4.00%	3.00%	3.00%	3.00%	3.00%	3.00%	
35																		
36		Growth factor - Textiles Garment production		1.00	0.91	0.94	1.00	1.09	1.22	1.42	1.64	1.90	2.20	2.54	2.95	3.41	3.95	
37				REF	-4.57%	1.00%	2.00%	3.00%	4.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	5.00%	
38				MED	-4.57%	0.00%	1.00%	2.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	3.00%	
39				LOW	-4.57%	-1.00%	0.00%	1.00%	1.00%	1.00%	1.00%	1.00%	1.00%	1.00%	1.00%	1.00%	1.00%	

Sugar Production

The sugar sub-sector energy service demand is developed using the projected growth rate in sugar cane production as the principal driver – and limitation on growth in the sub-sector. No elasticity factor or other factor was used.

Cement production

The cement sub-sector energy service demand is developed using the industry sector GDP growth as the principal driver, a construction sub-component elasticity, and a cement energy use elasticity factor (defined as the percentage change in energy consumption divided by the percentage change in GDP growth) [row 45], which is based on review of cement sector trends in the *2010 Economic Survey*. The current trend toward cement exports is to support strong near-term growth, but this trend is not expected to last for the long term. Therefore, the elasticity factor was varied over time (Row 46) to allow for adjustment I this trend. Historically, the construction related GDP growth relative to the industrial GDP growth was found to be highly variable, so a zero elasticity was used.

Iron and Steel

The steel sub-sector energy service demand is developed using the industrial component of GDP growth as the principal driver, and an elasticity factor (defined as the percentage change in energy consumption divided by the percentage change in GDP growth) [rows 48-54], which is based on expert judgment. While there are seven process-level demands for iron and steel, they are linked and so use the same values for the sub-sector elasticities.

Brick Kilns

The brick kiln sub-sector energy service demand is developed using the industry sector GDP growth as the principal driver, a construction sub-component elasticity and a brick kiln energy use elasticity factor (defined as the percentage change in energy consumption divided by the percentage change in GDP growth) as given on row 58, which is based on expert judgment. Historically, the construction related GDP growth relative to the industrial GDP growth was found to be highly variable, so a zero elasticity was used.

Fertilizer

The fertilizer sub-sector energy service demand is developed using the agricultural component of GDP growth as the principal driver, and an elasticity factor (defined as the percentage change in energy consumption divided by the percentage change in GDP growth) as given on row 62, which is based on expert judgment.

Other Industry

The Other Industry sub-sector energy service demand is developed using the industrial component of GDP growth as the principal driver, and an elasticity factor (defined as the percentage change in energy consumption divided by the percentage change in GDP growth) as given on row 65, which is based on expert judgment.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
39				LOW	-4.57%	-1.00%	0.00%	1.00%	1.00%	1.00%	1.00%	1.00%	1.00%	1.00%	1.00%	1.00%	1.00%	1.00%
40	Sugar Production																	
41	Sugar Cane Production Driver @ 2% per annum	2.00%	1.00	1.04	1.10	1.17	1.24	1.32	1.40	1.49	1.58	1.67	1.76	1.86	1.96	2.06	2.12	
42																		
43	Cement production																	
44	Construction GDP Intensity	0.00%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
45	Intensity factor - Cement production - export		1.00	1.04	1.10	1.14	1.14	1.10	1.04	0.98	0.92	0.87	0.82	0.77	0.72	0.68		
46				2.00%	2.00%	1.00%	0.00%	-1.00%	-2.00%	-2.00%	-2.00%	-2.00%	-2.00%	-2.00%	-2.00%	-2.00%		
47	Iron and Steel																	Post 2020 EI
48	Intensity factor - Iron and Steel Integrated Pig Iron	-1.00%	1.00	0.98	0.95	0.92	0.90	0.88	0.82	0.78	0.75	0.71	0.68	0.65	0.62	0.60		-1.50%
49	Intensity factor - Iron and Steel Integrated Cast Billet	-1.00%	1.00	0.98	0.95	0.92	0.90	0.88	0.82	0.78	0.75	0.71	0.68	0.65	0.62	0.60		-1.50%
50	Intensity factor - Iron and Steel Integrated Steel Products	-1.00%	1.00	0.98	0.95	0.92	0.90	0.88	0.82	0.78	0.75	0.71	0.68	0.65	0.62	0.60		-1.50%
51	Intensity factor - Iron and Steel Integrated Other Processes	-1.00%	1.00	0.98	0.95	0.92	0.90	0.88	0.82	0.78	0.75	0.71	0.68	0.65	0.62	0.60		-1.50%
52	Intensity factor - Iron and Steel Independent Billets (Independent)	-1.00%	1.00	0.98	0.95	0.92	0.90	0.88	0.82	0.78	0.75	0.71	0.68	0.65	0.62	0.60		-1.50%
53	Intensity factor - Iron and Steel Independent Construction steel	-1.00%	1.00	0.98	0.95	0.92	0.90	0.88	0.82	0.78	0.75	0.71	0.68	0.65	0.62	0.60		-1.50%
54	Intensity factor - Iron and Steel Independent Other (Independent)	-1.00%	1.00	0.98	0.95	0.92	0.90	0.88	0.82	0.78	0.75	0.71	0.68	0.65	0.62	0.60		-1.50%
55																		
56	Brick Kilns																	
57	Construction GDP Intensity	0.00%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	Post 2020 EI
58	Intensity factor - Brick Kiln Production	-1.00%	1.00	0.98	0.95	0.92	0.90	0.88	0.82	0.78	0.75	0.71	0.68	0.65	0.62	0.60		-1.50%
59																		
60	Fertilizer																	
61	Agricultural GDP Driver		1.00	1.05	1.18	1.32	1.49	1.69	1.98	2.11	2.30	2.52	2.75	3.01	3.28	3.59		
62	Intensity factor - Fertilizer production	-0.50%	1.00	0.99	0.98	0.96	0.95	0.93	0.92	0.90	0.89	0.88	0.86	0.85	0.84	0.83		
63																		
64	Other Industry																	
65	Intensity factor - Other industry	-1.50%	1.00	0.97	0.93	0.89	0.85	0.80	0.75	0.71	0.66	0.63	0.59	0.55	0.52	0.49		-2.00%

Commercial

The commercial sector energy service demands are developed for the following end-use applications. All demands are in units of PJ.

- Space Heating
- Water Heating
- Space Cooling (Fans and AC)
- Lighting
- Refrigeration
- Electrical Appliances
- Other

The process of developing the commercial demand projection is described below.

- The services component of GDP growth (row 16) is the principal driver for this sector, and each end-use sector is related to the GDP growth through an elasticity factor [C17-C23]. The elasticity factor is defined as the percentage change in energy consumption divided by the percentage change in GDP growth. The elasticity factors are either zero or negative, which if zero means that energy use grows at the same rate as GDP grows, or if negative means that energy use grows more slowly than

GDP growth. The elasticities are used to calculate factors that when multiplied by the GDP growth gives the effective energy growth. The commercial sector elasticities are based on expert judgment.

- The demand drivers are calculated [rows 26-32] and are linked to the Drivers sheet. The actual demand projection in rows 3 to 11 are calculated from the useful energy demand values for BY 2007, which are copied to Col-D from the VT_PAK_COM template.
- Aggregations of the energy individual end-use demand projections are collected in rows 3 to 11.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
11																	
12																	
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22																	
23																	
24																	
25																	
26																	
27																	
28																	
29																	
30																	
31																	
32																	

Agriculture

The agriculture sector energy service demands are developed for the following end-use applications. All demands are in units of PJ.

- Water pumping
- Tractors – Haulage
- Tractors – Farm Op.
- Other Use

The process of developing the agriculture demand projection is described below.

- The agricultural component of GDP growth [row 13] is the principal driver for this sector, and each end-use sector is related to the GDP growth through an elasticity factor [cells C14-C17]. The elasticity factor is defined as the percentage change in energy consumption divided by the percentage change in GDP growth. The elasticity factors are either zero or negative, which if zero means that energy use grows at the same rate as GDP grows, or if negative means that energy use grows more slowly than GDP growth. The elasticities are used to calculate factors that when multiplied by the GDP growth gives the effective energy growth. The agricultural sector elasticities are based partly on expert judgment as well as data from the Energy Yearbook that was used to calculate a historical elasticity factor for the entire sector, which was -1.05%.
- Aggregations of the energy demand projections are collected in rows 3 to 8.
- The demand drivers are calculated [rows 20-23] and are linked to the Drivers sheet. The actual demand projection in rows 3 to 8 are calculated from the useful energy demand values for BY 2007, which are copied to Col-D from the VT_PAK_ARG template.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Agriculture Sector - Subsector Demand Projections, PJ/a																
2	Agriculture																
3	Name	Description	Units	2007	2009	2012	2015	2018	2021	2024	2027	2030	2033	2036	2039	2042	2045
4	AWP	Water pumping	PJ	13.3	13.9	15.3	16.9	18.8	20.9	23.2	25.4	27.3	29.4	31.6	34.1	36.7	39.5
5	ATH	Tractors - Haulage	PJ	3.5	3.6	3.9	4.3	4.8	5.3	5.8	6.3	6.7	7.2	7.7	8.2	8.8	9.4
6	ATF	Tractors - Farm Op.	PJ	16.3	16.8	18.2	19.9	21.8	23.8	26.0	28.0	29.7	31.5	33.4	35.4	37.6	39.8
7	AOE	Other Use	PJ	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.8	0.8	0.9	0.9	1.0	1.1	1.2
8		Total	PJ	33.4	34.7	37.9	41.6	45.9	50.6	55.6	60.5	64.6	69.0	73.7	78.7	84.1	89.8
9		Annual Growth Rate			1.0%	3.00%	3.20%	3.30%	3.31%	3.21%	2.81%	2.22%	2.22%	2.22%	2.23%	2.23%	2.23%
10												2.90%					
11																	
12	Agricultural GDP & Elasticities																
13	AGR	GDP driver		1.00	1.05	1.18	1.32	1.49	1.69	1.90	2.11	2.30	2.52	2.75	3.01	3.28	3.59
14		Intensity factor - Water pumping	-0.50%	1.00	0.99	0.98	0.96	0.95	0.93	0.92	0.90	0.89	0.88	0.86	0.85	0.84	0.83
15		Intensity factor - Haulage	-0.75%	1.00	0.99	0.96	0.94	0.92	0.90	0.88	0.86	0.84	0.82	0.80	0.79	0.77	0.75
16		Intensity factor - Farm Op.	-1.00%	1.00	0.98	0.95	0.92	0.90	0.87	0.84	0.82	0.79	0.77	0.75	0.72	0.70	0.68
17		Intensity factor - Other Use	-0.50%	1.00	0.99	0.98	0.96	0.95	0.93	0.92	0.90	0.89	0.88	0.86	0.85	0.84	0.83
18																	
19	Agricultural Demand Drivers																
20	AWP	Agriculture Water pumping		1.00	1.04	1.15	1.27	1.41	1.57	1.74	1.91	2.05	2.21	2.38	2.56	2.76	2.97
21	ATH	Agriculture Tractors - Haulage		1.00	1.04	1.13	1.25	1.38	1.52	1.67	1.81	1.94	2.07	2.21	2.36	2.52	2.70
22	ATF	Agriculture Tractors - Farm Op.		1.00	1.03	1.12	1.22	1.34	1.46	1.60	1.72	1.83	1.94	2.06	2.18	2.31	2.45
23	AOE	Agriculture Other Use		1.00	1.04	1.15	1.27	1.41	1.57	1.74	1.91	2.05	2.21	2.38	2.56	2.76	2.97

Transport

The transport sector energy service demands are developed for the following end-use applications. There are two sub-categories of demands: passenger transport and freight transport. Most of the passenger transport demand is expressed in million passenger kilometers (mpkm) except for aviation, which is in PJ. Most of the freight transport demand is expressed in million ton kilometers (mtkm) except for shipping, which is in PJ.

Passenger transport	Units
Buses	mpkm
Cars	mpkm
Two-wheelers	mpkm
Three-wheelers	mpkm
Taxis	mpkm
Minivans	mpkm
Rail Passenger	mpkm
Aviation	PJ
Freight transport	Units
Trucks	mtkm
Delivery Vans	mtkm
Rail Freight	mtkm
Shipping	PJ

The process of developing the transport demand projections is described below.

- The overall GDP growth (row 23) is the principal driver for this sector, and each end-use sector is related to the GDP growth through an elasticity factor, given in cells C24 to C33. The elasticity factor is defined as the percentage change in energy consumption divided by the percentage change in GDP growth. The elasticity factors are either zero or negative, which if zero means that energy use grows at the same rate as GDP grows, or if negative means that energy use grows more slowly than GDP growth. The elasticities are used to calculate factors that when multiplied by the GDP growth gives the effective energy growth. The transport sector elasticities are based largely on projections made in the Pakistan Transport Plan Study funded by JICA. In addition, several of the elasticity factors were modified post-2030 to allow for anticipated changes in current trends.
- Aggregations of the energy demand projections are collected in rows 3 to 15.
- The demand drivers are calculated [rows 36-47] and are linked to the *Drivers* sheet. The actual demand projection in rows 3 to 15 are calculated from the useful energy

demand values for BY 2007, which are copied to Col-D from the *VT_PAK_TRN* template.

Transport Sector - Subsector Demand Projections																	
Name	Description	Units	2007	2009	2012	2015	2018	2021	2024	2027	2030	2033	2036	2039	2042	2045	
Transport																	
4	TBU	Buses	mpkm	245,790	203,203	277,344	306,061	354,506	410,377	471,402	530,266	613,341	706,570	810,936	933,025	1,116,095	1,312,534
5	TCA	Cars	mpkm	47,180	52,985	57,435	66,299	80,403	97,335	116,995	138,786	166,671	197,995	236,390	283,674	342,767	414,834
6	TTR	Trucks	mpkm	27,537	29,795	31,009	35,707	42,842	49,354	57,501	66,732	77,203	89,647	100,005	114,009	132,205	152,176
7	TVN	Delivery Vans	mpkm	2,904	2,295	2,412	2,793	3,362	3,738	4,367	5,091	5,843	6,634	7,569	8,681	10,006	11,594
8	TPW	Two-wheelers	mpkm	62,454	68,303	74,070	84,365	100,844	120,191	142,310	167,497	196,735	230,763	262,695	305,676	357,941	421,126
9	TSW	Three-wheelers	mpkm	5,219	6,307	7,500	8,871	10,530	12,154	14,239	16,307	18,603	21,230	24,204	28,000	32,200	36,200
10	TTX	Taxis	mpkm	11,676	12,556	13,706	15,692	19,745	23,343	28,452	33,153	38,507	42,199	48,620	56,955	66,541	76,776
11	TMV	Minivans	mpkm	148,830	159,411	167,937	195,325	234,934	249,451	295,443	325,530	371,909	429,004	495,918	577,430	675,916	795,006
12	TRP	Rail Passenger	mpkm	25,446	28,336	29,841	32,931	36,189	44,705	50,721	57,995	66,623	76,601	87,619	100,689	121,496	147,043
13	TRF	Rail Freight	mpkm	5,454	6,031	6,437	7,664	9,300	11,252	13,525	16,459	19,267	22,208	25,727	29,907	35,060	41,244
14	TAV	Aviation	PJ	22.3	25.6	28.3	32.9	40.2	48.9	59.1	71.0	85.1	100.2	118.5	141.0	168.5	202.4
15	TSH	Shipping	PJ	0.40	0.44	0.48	0.54	0.65	0.77	0.91	1.07	1.26	1.45	1.68	1.96	2.30	2.70
16		Private Transport Annual Growth Rate			3.86%	3.25%	5.67%	6.35%	6.27%	7.86%	7.58%	7.49%	7.86%	6.76%	6.42%	6.75%	6.00%
17		Public Transport Annual Growth Rate			3.73%	3.00%	5.43%	6.02%	7.54%	7.60%	7.28%	7.30%	7.42%	7.63%	7.57%	6.25%	6.52%
18		Freight Annual Growth Rate			4.9%	3.65%	6.15%	6.80%	6.65%	8.30%	7.98%	7.68%	6.79%	6.98%	7.25%	7.54%	7.6%
21	Transport GDP & Elasticities																
22	GDP driver		100	110	122	141	171	206	248	296	353	420	501	601	725	879	
23	Intensity factor - Bus Transport & Minivan	-150%	100	0.97	0.93	0.89	0.85	0.81	0.77	0.74	0.71	0.69	0.67	0.65	0.63	0.61	
24	Intensity factor - Passenger Transport - Cars	0.00%	100	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
25	Intensity factor - Freight Transport - Road	-100%	100	0.50	0.95	0.52	0.50	0.87	0.84	0.82	0.79	0.76	0.72	0.69	0.66	0.63	
27	Intensity factor - Passenger Transport - 2-wheelers	-500%	100	0.99	0.99	0.95	0.95	0.93	0.92	0.90	0.89	0.86	0.84	0.81	0.79	0.77	
28	Intensity factor - Passenger Transport - Taxi & 3-wheelers	-650%	100	0.99	0.99	0.95	0.95	0.93	0.92	0.90	0.89	0.86	0.84	0.81	0.79	0.77	
29	Intensity factor - Passenger Transport - Rail	-150%	100	0.97	0.93	0.89	0.85	0.83	0.77	0.74	0.73	0.72	0.71	0.70	0.69	0.68	
30	Intensity factor - Freight Transport - Rail	0.00%	100	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.97	0.94	0.91	0.89	
31	Intensity factor - Air Transport	100%	100	1.07	1.05	1.08	1.12	1.15	1.18	1.22	1.26	1.28	1.30	1.31	1.33	1.35	
32	Air Transport - Autonomous Efficiency Improvement	120%	100	0.98	0.95	0.95	0.95	0.89	0.89	0.84	0.82	0.80	0.79	0.77	0.75	0.73	
33	Intensity factor - Ship Transport	-90%	100	0.99	0.99	0.96	0.95	0.93	0.92	0.90	0.89	0.88	0.84	0.81	0.79	0.77	
34	Transport Demand Drivers																
35	Transport Buses		100	107	113	125	144	167	192	219	250	288	333	388	454	534	
37	Transport Cars		100	110	122	141	171	206	248	296	353	420	501	601	725	879	
38	Transport Trucks		100	109	116	130	153	179	209	242	280	328	383	446	520	606	
39	Transport Delivery Vans		100	108	116	130	153	179	209	242	280	328	383	446	520	606	
40	Transport Two-wheelers		100	109	119	126	161	192	226	269	315	363	420	489	573	674	
41	Transport Three-wheelers		100	109	119	126	161	192	226	269	315	363	420	489	573	674	
42	Transport Taxis		100	109	119	126	161	192	226	269	315	363	420	489	573	674	
43	Transport Minivans		100	107	113	125	144	167	192	219	250	288	333	388	454	534	
44	Transport Rail Passenger		100	107	113	125	144	167	192	219	257	301	354	419	497	594	
45	Transport Rail Freight		100	110	122	141	171	206	248	296	353	420	501	601	725	879	
46	Transport Aviation		100	110	122	142	173	209	254	305	366	431	500	586	694	830	
47	Transport Shipping		100	109	119	126	161	192	226	269	315	363	420	489	573	674	

7. Reference Scenario Tailoring

Section IV.C.2 provides detailed descriptions of the scenario files *REF-<Area>*. As described above, such files contain information for tailoring the reference scenario, such as power plant build rates, demand sector fuel share evolution, etc. In this model there are three core files:

- REF-ELC helps model existing plant operation levels, build rates of new technologies, minimum generation from specific plant types and load shedding. It also has a *Supply* worksheet that restricts the annual supply of coal by region, and the import of gas via the central Asian pipeline option.

Variations of this file used in sensitivity analysis include *REF-ELC_noFO* (to switch off forced operation) and *REF-ELC-LS2016* (to extend the time period over which load shedding occurs)

- REF-FRs provides the COM_FR attribute values, which define the fraction of demand for a given energy service during a specific timeslice.
- REF-DMD contains a large number of user constraints for controlling energy consumption levels across different sectors / subsectors, and technology uptake rates.

D. Special TIMES Features for Data Specification and Model Tailoring

VEDA and TIMES have some powerful facilities that need clarification to be able to properly take full advantage of them. Three that are particularly important are:

- the rules and options available in the VEDA settings files (*BY_Trans* and *SysSettings*)
- how the interpolation rules are applied
- the formulation of user defined constraints

Each of these is discussed in the sections that follow.

1. BY_Settings and SysSettings

As discussed briefly in Section II.A, VEDA uses two key files to configure and set defaults for the model and particular data elements. Actually, the BY_Trans file is only used to inhibit investment in existing refineries, gas pipelines, and "X"-process technologies by means of a ~TFM_INS upper limit and interpolation rule default overrides. It is not expected that BY_Trans and SysSettings files will not need to be adjusted (other than for periods as discussed below).

SysSettings has a series of tabs handling particular aspects of configuring VFE (see VedaSupport for explanation):

- **Region-Time Slices:** Provides the general specifications to indicate that Pak-IEM is a single region model called PAK, with all BY templates incorporating this name as VT_PAK<sector>, as discussed in Section II.A. It also indicates the season and day-night time-slices that are defined for Pak-IEM.
- **TimePeriods:** Indicates the various group of milestone years for which this TIMES model is to be run, with the number of years in each period maintained in the ~TimePeriods lists. Any of these milestone lists may be selected from the VFE CaseManager at run time.
- **Interpol_Extrapol_Defaults:** Controls how data is handled in terms of interpolation and/or extrapolation rules for individual attributes. For Pak-IEM some overrides are specified for various attributes that normally are left alone. See the discussion of Interpolation Rules further below and in the next section.
- **Import Settings:** These are VFE switches controlling optional operations during the SYNC process (also discussed further below).
- **Constants:** Contains the global parameters covering the overall social discount rate, the overall fraction of the year for each time slice, and the peak reserve margin requirements.

Note that in general it is not expected that the SysSettings file needs updating/intervention by the analyst, with the notable exception of the TimePeriods managed via the VFE Advanced Milestone Years facility.

Returning to the Interpol_Extrapol_Defaults sheet, the first section sets the override interpolation options (by specifying Year-0) for the various attributes that are not normally interpolated (see next section). Here in particular the rule 5 = interpolation and forward extrapolation is activated for FLO_SHAR/AFA/COM_PKRSV, 15 = interpolation migrated to ends forward extrapolation is activated for CAP-BND and ACT_BND to handle the fact that data years and milestone years may be different, and 12 = interpolation migrated to ends, extrapolation with EPS is activated for NCAP_BND so that any fixed forced new build value is applied only once.

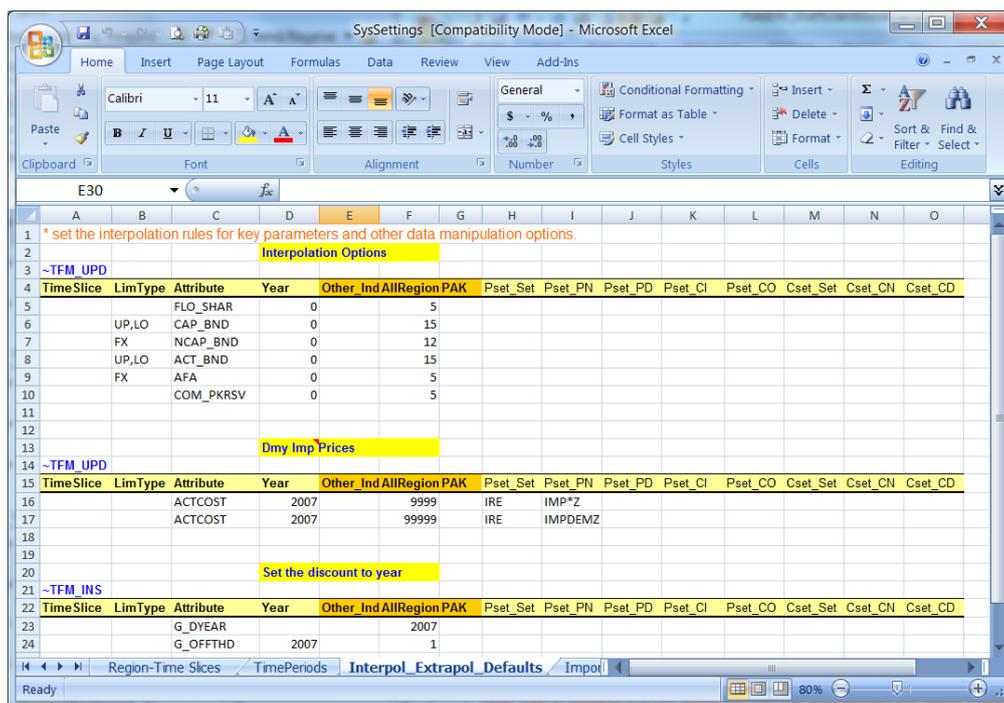


Figure 14: SysSettings Interpolation and Data Defaults

Next on this tab are some data settings to specify the value to be used for the ZZDMY "backstop" process operation cost, which are set high to deter them coming into the model except when essential. Finally, this tab sets the year to which all discounting is to occur, and contains a switch (G_OFFTHD=1 to activate) to instruct the TIMES code to align START/bound specification to ensure they line up with data/model years when different.

For Pak-IEM, some important VFE Import Settings are activated (by entering 1). These are, most notably, in the order activated:

- checking for # entries in the workbooks rather than accepting the values are 0
- requesting VFE creates backstop options for each commodity
- requesting VFE creates backstop options for each demand

~ImpSettings	
Option	Value
Check #DIV/0 and #REF errors in Templates	1
Create Dummy Imports for Energy and Material Commoditi	1
Create Dummy Imports for Demands	1
Generate Vintage Bounds	0

Figure 15: VFE Import/SYNC Switch Settings

2. Interpolation Rules

TIMES has powerful interpolation facilities that take some time and experience to fully understand and correctly exploit. There is a full write-up, TIMES-Interpolation, that can be found on the Documentation page of the ETSAP website covering all aspects of the TIMES interpolation rules and how they are applied. There is also a shorter write-up with the basic information (TIMES-Interpolate) in the DOC folder in the VEDA folder. The basic philosophy and approach is that almost all non-constraining parameters (constraining being the various bounds, RHSs) are interpolated and extended constant. What this means is that by just providing a value in a single (initial) year, that value will be applied across all model years for

a particular run, thus permitting full specification for the parameter with a single entry for any run periods. However, for constraining parameters, the default is to not apply any interpolation/extrapolation, which means that VFE will just accept the value for the year (period with migration) specified. The set of interpolation/extrapolation override settings is shown below.

As shown in SysSettings, and found in various Scenario files, the user overrides the default by specifying Year=0 in the input template. So when a 0 is found in the VFE-Browse when examining the input data it should serve as a trigger that a certain interpolation/extrapolation rule is to apply to that particular instance of the data. Migrate handles the situation where the data year does not coincide with a model year requiring that data falling within the period is moved to the model year.

Action	Option code	Applies to
Default interpolation/extrapolation (see above)	0 (or none)	All
No interpolation/extrapolation	< 0	All
Interpolation but no extrapolation	1	All
Interpolation, but extrapolation with EPS	2	All
Full interpolation and extrapolation	3	All
Interpolation and backward extrapolation	4	All
Interpolation and forward extrapolation	5	All
Migrated interpolation/extrapolation within periods	10	Bounds, RHS
Interpolation migrated to end-points, no extrapolation	11	Bounds, RHS
Interpolation migrated to ends, extrapolation with EPS	12	Bounds, RHS
Interpolation migrated to ends, backward extrapolation	14	Bounds, RHS
Interpolation migrated to ends, forward extrapolation	15	Bounds, RHS
Log-linear interpolation beyond YEAR	YEAR (≥ 1000)	All

Figure 16: TIMES Interpolation/Extrapolation Options

III. VEDA Front End (VEDA-FE) for Managing the Model Input

VEDA-FE (VFE) provides a comprehensive and powerful framework for managing all aspects of working with the Pak-IEM input data as maintained in the various templates discussed in the previous section. While the individual data entries are made in the templates, VFE enables the Pak-IEM analyst to effectively and efficiently review and understand the resulting energy system, as well as access specific data directly to enable the model to be refined and maintained. The four main VFE components for managing the templates and data are discussed here and consist of:

- **Navigator** – for handling the templates
- **Browse** – for examining (and adjusting) the input data
- **RES Diagramming and Process/Commodity Masters** – for viewing the Reference Energy System network flows and interrelationships, and in the case of the Masters - also viewing the component details (e.g., set membership, timeslice level)
- **Case Manager** – for submitting and keeping track of model runs

There is excellent interactive Help available at www.KanORS.com/VedaSupport that explains all aspects of VEDA. This write-up assumes that the reader is fully familiar with the VedaSupport site and focuses on how to work with Pak-IEM using VEDA.

VFE is invoked from the associated icon on the desktop. It will open with the last model used. To change to Pak-IEM, or any other model (e.g., TIMES_DEMO) see the VEDA-Navigator discussion in the next section.

A. VEDA-FE Template and Data Management

Figure 17 shows VFE with the VEDA-Navigator, Browse and Case Manager all open simultaneously, as these three modules are the most often used of the VEDA tools. Once setup along these lines, VFE will open the next time with the same model and components. The next sections will explain how to use these three modules in detail.

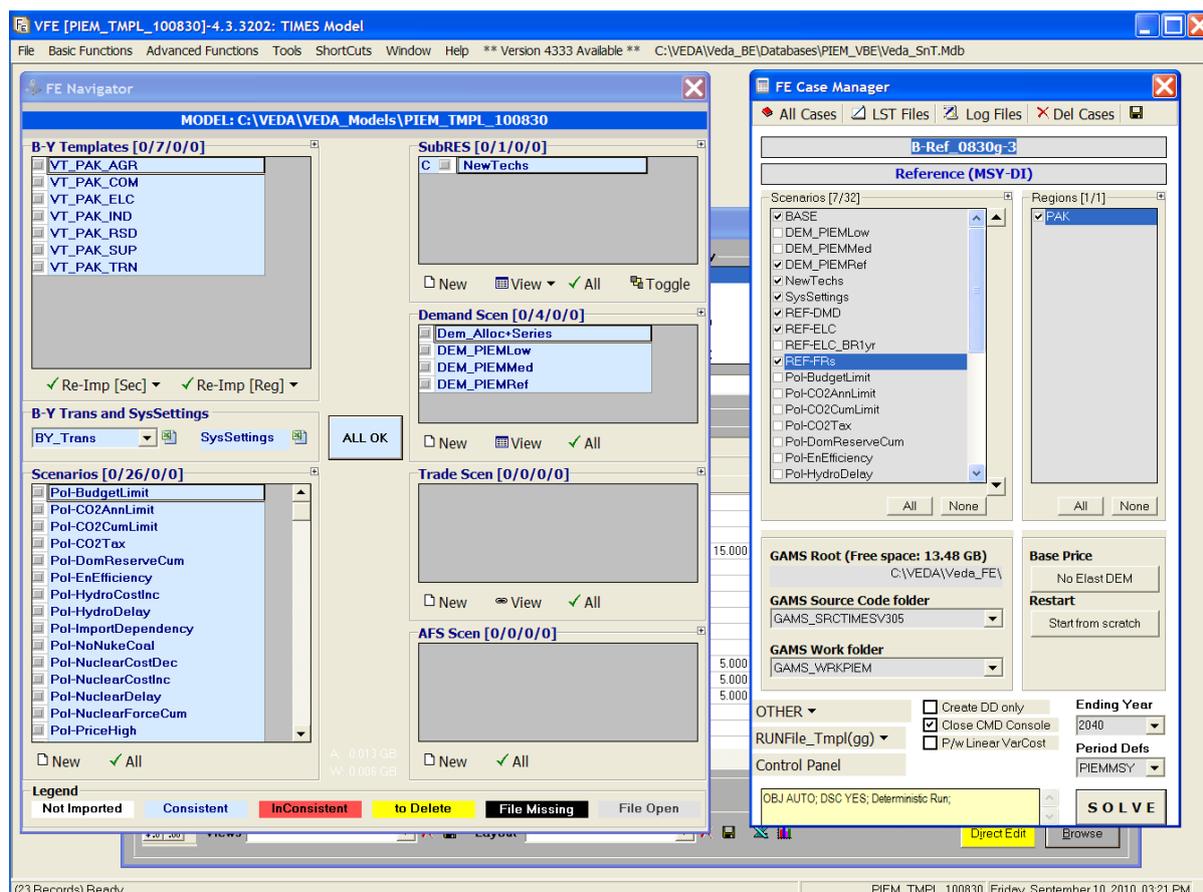


Figure 17: VFE Navigator, Case Manager and Browse (in back)

1. VEDA-Navigator

The VEDA-Navigator serves as the heart of the VEDA-FE system managing all the Excel templates comprising Pak-IEM. It is the main vehicle for accessing the data templates and keeping the model organized and synchronized. Synchronize (via the SYNC/ALL OK button) is the process which ensures that the model data in the VEDA database (which is comprised of the Access files in the Databases folder) is fully consistent with the latest version of the individual Excel templates. The Navigator is divided into quadrants, along the lines of the folder structure under the VEDA_Models directory mentioned above (except that Pak-IEM does not use the Trade component related to multi-region models nor AFS for which other VFE features are employed). In each quadrant are listed all the files corresponding to those recognized by VFE as system templates. Note that any Pak-IEM workbooks that do not

conform to the VEDA naming convention will not be shown. A good example is the Pak-IEM_EnergyBalance workbook.

The most often used VEDA-Navigator features are discussed below and indicated in Figure 18 according to the numbers.

1. **Selecting the model instance** – by clicking the area with the model name, VEDA will navigate to the currently shown model folder (in this example \VEDA_Models\PIEM_TMPL_100830). From there the user can select a newer version of Pak-IEM, or select another VEDA model.
2. **Open folder** – by clicking on the header row for any of the groups, VEDA will open the folder containing all the workbooks for that group.
3. **Open BY_Trans or SysSettings** – by double-clicking on the Excel symbol, either of these files can be opened.
4. **Opening any individual template** – by double-clicking on any of the individual template names, one or more of the templates can be opened.
5. **SYNChronizing the model** – by clicking on the SYNC button, which is what the ALL OK button is transformed to when any of the model templates are not consistent with the VEDA database, VFE will re-import those templates into the database. Once complete, the button will return to its ALL OK status.

For each of the file groups or quadrants (plus SysSettings) there is a colored designator associated with it which will appear next to the Scenarios listed on the Case Manager, and can be clicked on to expand said window when the list to see more members if desired. {Note that the BY_Trans is lumped with the Base group to which it applies.}

Note that all the individual templates are colored-coded to reflect their current status, as indicated at the bottom of the Navigator form, where:

- **light blue** indicates that the date and time stamp of the file are consistent with the model database
- **white** indicates a newly added file
- **red** indicates that the file date and time stamp has changed since the last SYNC, and the current version of the file needs to be re-imported into the VEDA database
- **black/yellow** indicates files that used to be in the VEDA database but are now gone (e.g., have been renamed or deleted from the folder) and need to be removed from the Navigator listing (and database) on the next SYNC request

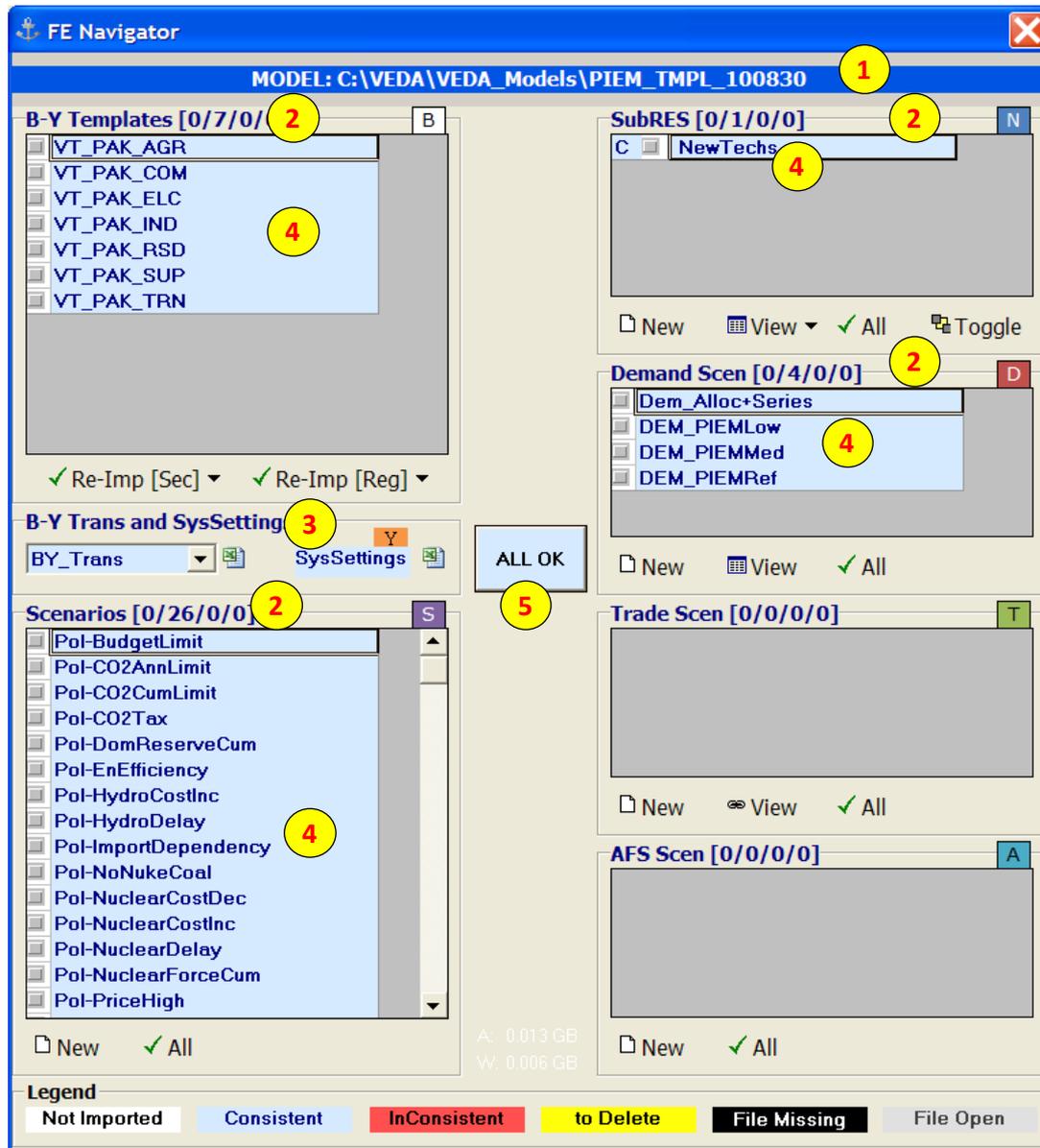


Figure 18: VFE-Navigator Template Manager

Whenever the content of any template is adjusted, such as when the file is closed after being opened through the Navigator, or if opened outside and modified, it will be inconsistent with the current database and need to be synchronized. To check if any files are inconsistent, the user must press the [F5] Refresh button or select Window/Refresh from the menu bar. The modified file will turn red, and at the same time the ALL OK button will change to SYNC (and turn red), to reinforce that some piece of information in a template is newer than what is current inside of VFE. Hitting the SYNC button will initiate the importing of all the flagged templates, as shown in Figure 19.

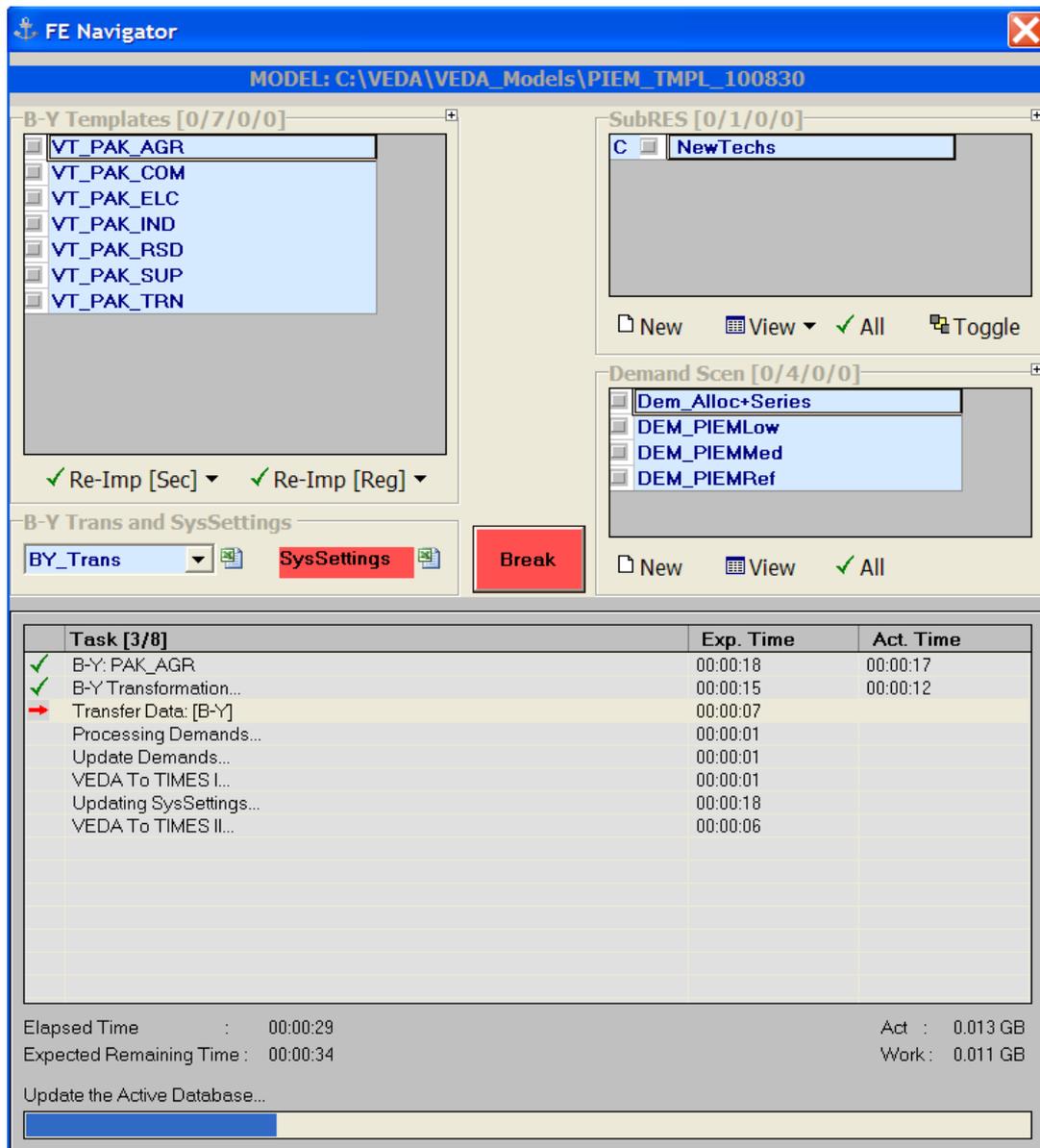


Figure 19: VFE-Navigator SYNC Status

If a problem or error is encountered during the SYNC process the ALL OK button will be left orange (rather than turn back to light blue), and it will be starred as an indicator that there is a pending problem with the last import operation. The error indicator will be reported in the status box, as can be seen in Figure 20. [Note: the [INFO] error may be ignored, as it warns that some process does not have a fuel in/out, but these are internal special VT_processes used in the fuel share User Constraints (discussed in the Section IV.4.1.)

For most such errors one can click on the error message, and VFE will open the problem template in the cell where the error occurs. If it is not possible to fully resolve the location of the error, VFE will identify the workbook and sheet or nature of the error. For this example, Figure 21 shows that the first error refers to the [INFO] error, and more details are reported in a text box, which can be opened by double-clicking. The second error identifies an improper attribute (XEFF instead of EFF), and if the Excel icon is double-clicked, VFE will open to the cell with the mistake.

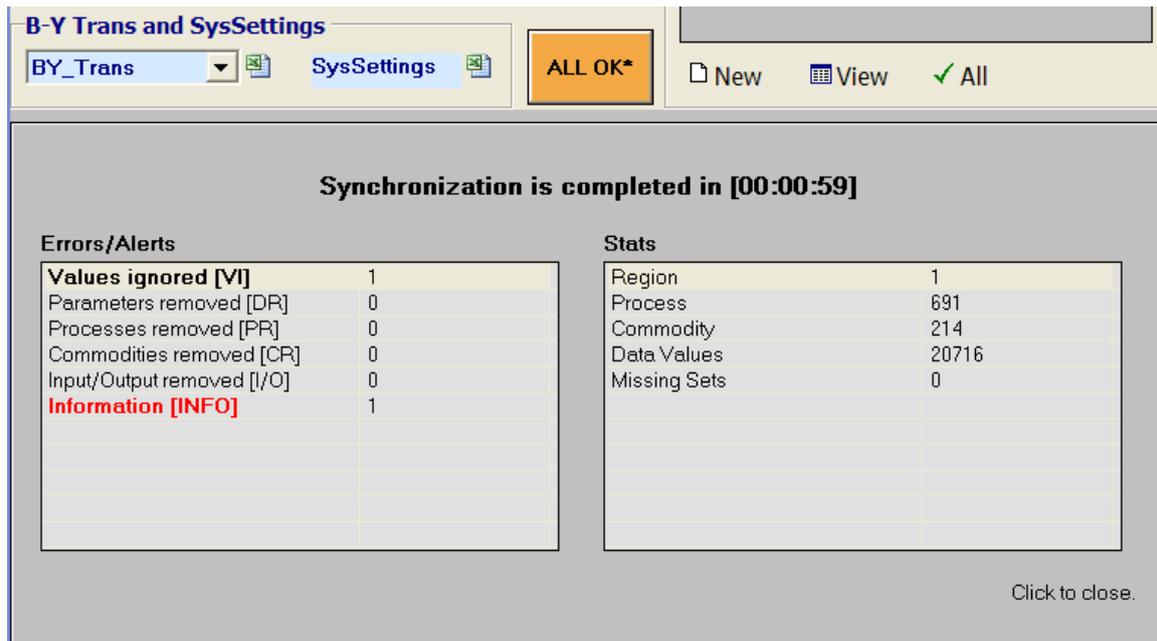


Figure 20: VFE-Navigator SYNC Error Report Status

	Scenario	Parameter	Region	Sector	Error	Workbook	Sheet	Check
1	-	-	-	-	Info: Processes with no Input/Output	QC_Processes_NoInOut-		
2	BASE	-	PAK	AGR	VI: Invalid Info XEFF	VT_PAK_AGR	Agriculture	

Figure 21: VFE-Navigator SYNC Error Details

Another kind of SYNC error that one may encounter occurs when there are references in a User Constraint (UC) template to Sets defined in VEDA-BE and the VBE SnT file is not properly "connected" to VFE, as was mentioned at the beginning of this section. Under such circumstances the error message, as shown in Figure 22, will occur, indicating the scenario file (though not sheet) and the unrecognized set. One will need to properly connect the SnT file (see next section) and re-import the UC template to have the UCs properly established.

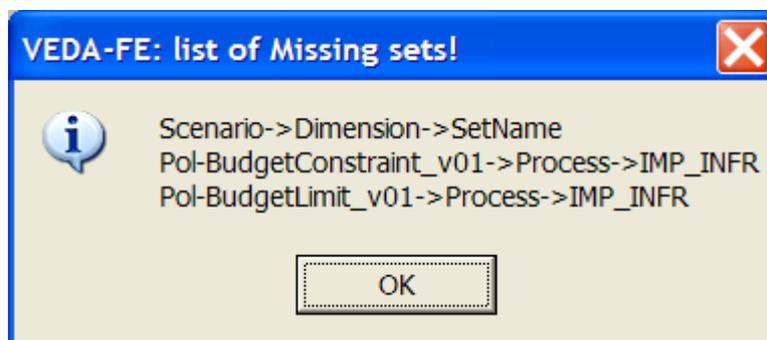


Figure 22: VFE-Navigator SYNC UC Set Reference Error

On some computers there can also be mystery Excel "crash" messages that are encountered on only some computers, which has been identified as being associated with embedded images and figures (of which there are many in the templates) but not resolved

by other than removing all such entities. This is annoying but does not cause any actually problem for VFE. The Restart box should be unchecked and the Don't Send button hit each time the form displayed in Figure 23 appears.

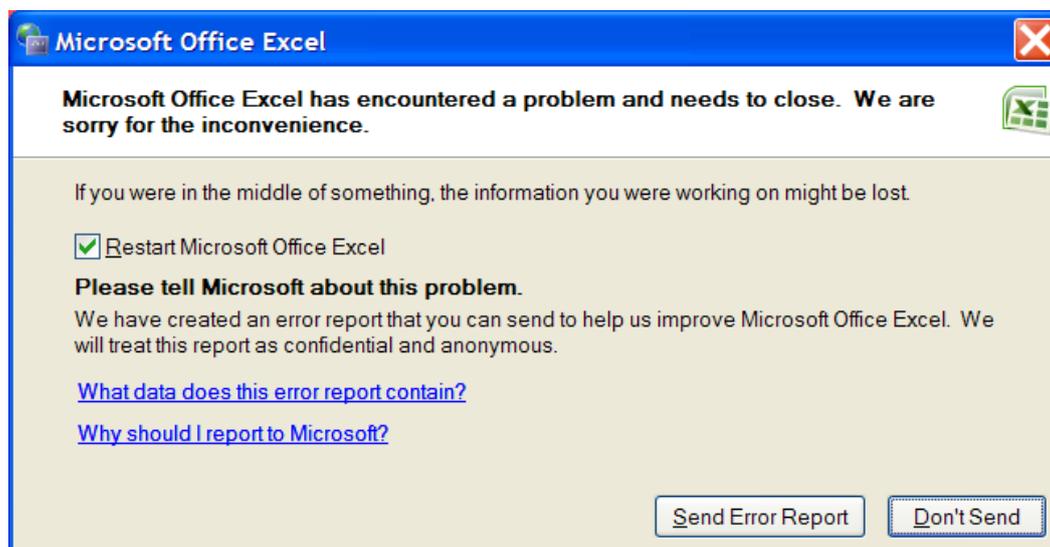


Figure 23: VFE-Navigator SYNC Excel "Crash" Warning

2. VEDA-Browse

After the templates are imported into VFE the best way to view the model data and learn how the underlying energy system is being represented is to use the other powerful features of VEDA, beginning with VEDA-Browse, which is an effective and efficient way to view (and change) the model data. As shown in Figure 24, the core components and functions of the VFE Browser are:

1. **Component Selection Lists** – where all instances for each of the basic data components are listed
2. **Component Set Lists⁵** – where the sets defined in VBE, or internal to TIMES, can be selected to limit the items displayed in the corresponding list box
3. **Browse Area** – where all data associated with the selected components is presented in a dynamic data cube
4. **Browse / Edit Mode Buttons** – to retrieve and control the mode of access to the underlying template data
5. **Selection and Cube Layout Controls** – to retain a particular combination of list selection criteria or impose a previously established layout for the cube on the current information
6. **Component Search Criteria** – allows for subsets of the component lists to be short-listed and then selectively selected according to matching criteria

⁵ VFE and VBE "talk" to each other by means of the VBE Sets&Tables (SnT) file. This connection is created by using the Tools/User Options/File Locations/Veda-BE Database option, and then reflected on the menu line, as can be seen on the Navigator Figure 5. Note that for PIEM VFE should always be connected to the \VEDA\VEDA_BE\Databases\PIEM_VBE\Veda_SnT.

VEDA View versus TIMES View. Before discussing each of these VFE Browse features we first need to explain that VEDA works with two views of the model data. The VEDA view displays the parameter names as used in VEDA, which is the way most of the data was entered into the templates, and is the view most often recommended, so that the connection between the input data and what is presented in Browse is clear. The TIMES view presents the parameter names "translated" to those actually used in the TIMES model generator GAMS code, which for certain attributes may be different to the VEDA conventions (see the Attribute Master, section IV.D.2.a, which contains a table with the TIMES attributes and their VEDA-View equivalent (aliases). The one instance when the User must use the TIMES view in VFE Browse is when details of User Constraints (UCs) are to be examined. Due to the way VEDA handles their construction they can only be viewed in TIMES view, and on the RES, which will be presented later.

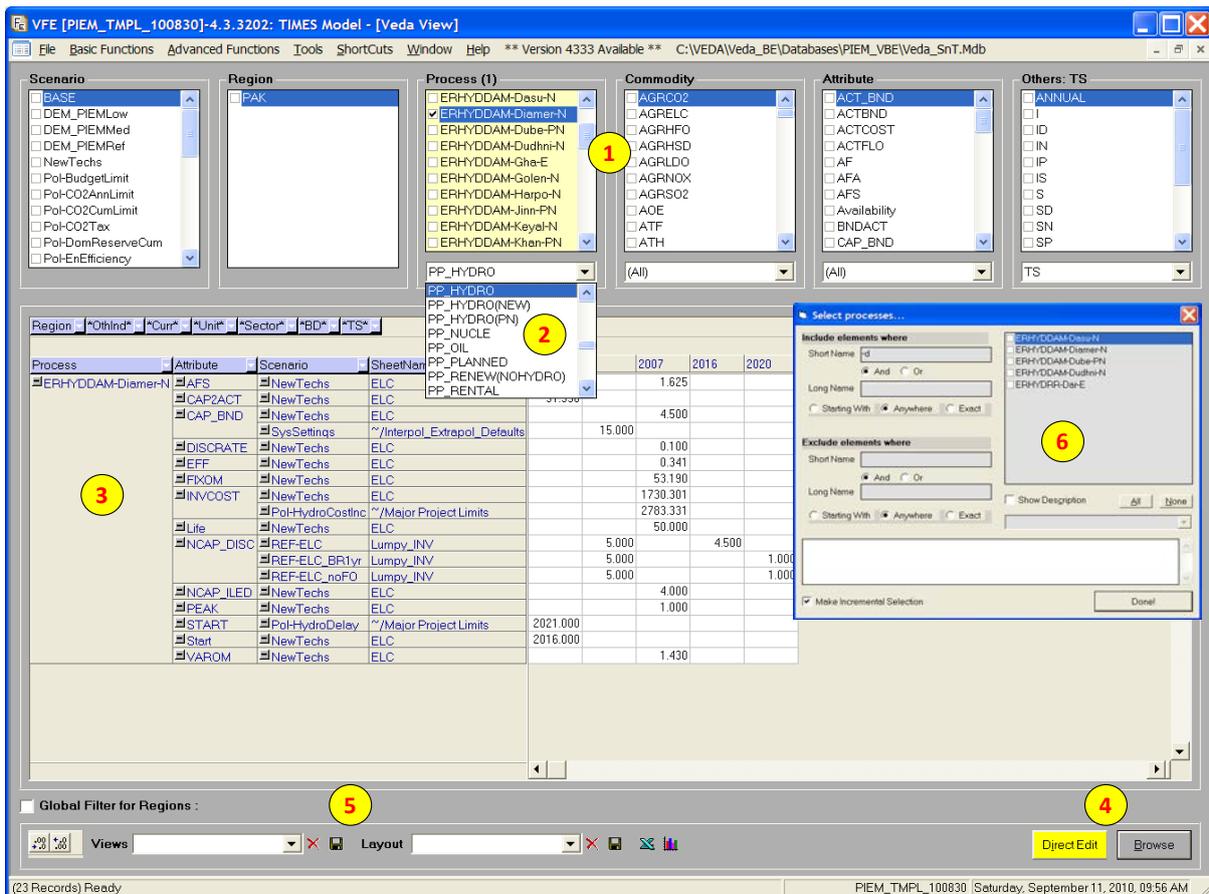


Figure 24: VFE-Browse Components

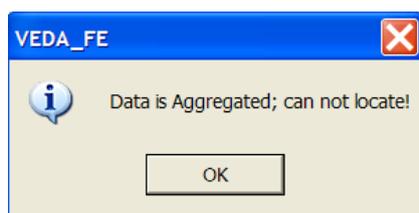
Selecting Data in VFE-Browse. The selection list is where one starts in terms of preparing to view model data via Browse. Most often the focus is the process list, where one is interested in viewing data details for a single or multiple processes.. To make a selection either find (using quick-type if desired) the desired item(s) and simply check [1], or limit the list by means a Set [2] or use the search criteria [6]. Whenever a Set is active, the list is shaded yellow to indicate that the list is incomplete, that is it a short-list consisting of just those items that belong to the specified Set. The number of items currently selected is shown above the associate list, e.g., Processes (1). ***{This is important to keep in mind, because if items are checked from a previous selection, particularly in other lists, the resulting Browse may not show the desired information. For example, if the previous browse looked at the Agriculture Diesel commodity, and it was left checked when***

then requesting data on a power plant, nothing would be displayed as no power plant produces Agriculture Diesel.}

Once the desired information has been selected (checked in the appropriate list box), hitting the Browse button will display all the associated information in the data cube (other than UCs when in VEDA View). The initial orientation of the cube will be the default or last layout used, and the layout can be modified as needed. Pulling down the Layout list [5] will permit the selection of a previously saved layout (e.g., Process) which can be used to present the data in a consistent, more convenient format. Similarly, the Views list can be used to save particular selection criteria (e.g., all existing hydro plants) to facilitate recalling often used groups that are not explicitly declared as VBE Sets.

Note that layout dimensions sitting off/above the cube may also contain data that for certain Attributes are important at times (e.g., the BD bound type), or necessary to fully qualify the location of data on a row for editing (as discussed next). When a dimension "hides" more than a single entity its name will be displayed as *<dimension>*, as is the case for dimensions all but Region in Figure 10 above.

Editing Data in VFE Browse. VFE-Browse does much more than just present the data. It is fully integrated with the underlying templates and features two powerful means of accessing and changing the model input data. In the non-Direct Edit mode double-clicking on any cell in the Browse will either jump top the corresponding cell in the appropriate template, or present a message indicating that the "Data is Aggregated: cannot locate!" because the cell represents the summed value of multiple templates due to a dimension necessary to fully identify where the information resides being off (above) the cube. Bring the necessary dimension into view will then enable VFE to "jump" to the proper place in the workbook. **{Note that making a change in a template via the VFE-Browse "jump" facility still requires going to the VFE-Navigator at the end of the editing process, pressing [F5] to refresh the list (at which time the template just edited will be flagged for importing) and a SYNC operation preformed.}**



The alternate approach is the Direct Edit mode in VFE-Browse that allows the user to make changes directly in the VFE database. As shown in Figure 25, when the Direct Edit (DE) button is pressed, the data area is shaded yellow to reinforce that DE mode is active and upon double-clicking on a (fully qualified) cell, a dialog box is presented. Here a new value can be entered, with the option of retaining the old value and including a comment in the corresponding cell in the appropriate workbook. DE has the advantage of not requiring re-importing of the template as the change is made both in the VEDA database and in the workbook. So the next model run will include any change even though no SYNC operation was performed!

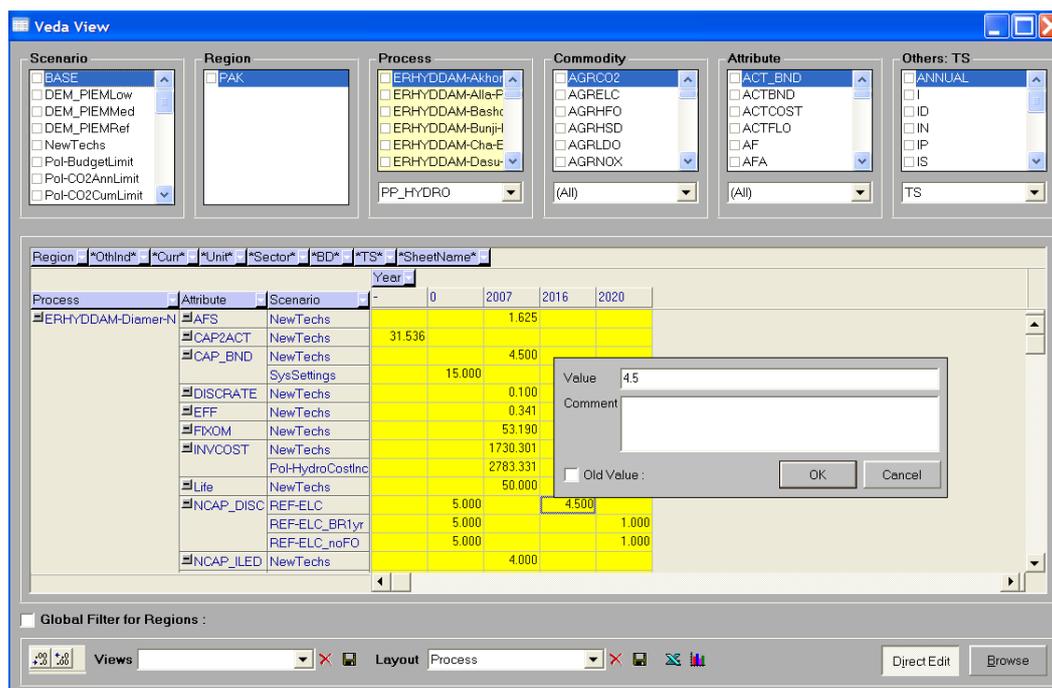


Figure 25: VFE-Browse Direct Edit

3. VEDA-FE Topology Viewing

Sometimes while viewing processes or commodities one wants to better understand the nature of the component and how it fits into the underlying energy system. Being able to visualize the interconnection between the various parts of the energy system is essential in order to fully understand the underlying the system. VFE provides the Process/Commodity Masters and RES diagramming facility to facilitate this aspect of learning Pak-IEM. The RES diagramming feature can be accessed via the Basic Function menu and the Process/Commodity Master forms can be accessed via the Advanced Function menu, and either can be accessed via right-mouse click from Browse.

3.1. Process/Commodity Master

As shown in Figure 26, the Process and Commodity Masters provide access to all the details associated with a particular system component, including the set membership, units, timeslice level, topology interconnections (that is the flows in/out of a process or the processes producing/consuming a commodity), vintaging flag, as well as the data (on the Data tab). The commodity or process type in the in/out lists are color coded according to type, and these can be double-clicked to enable cascading through the RES network. Elements can also be selected in the list box to the left of the main form. The Data tab provides a data cube similar to that provided via VFE-Browse, but only shows the TIMES view and does not have a layout control option at this time. The All Processes/Commodities tab provides a condensed table characterizing all processes/commodities, and is the same regardless of which item is selected – and appears to be of limited usefulness.

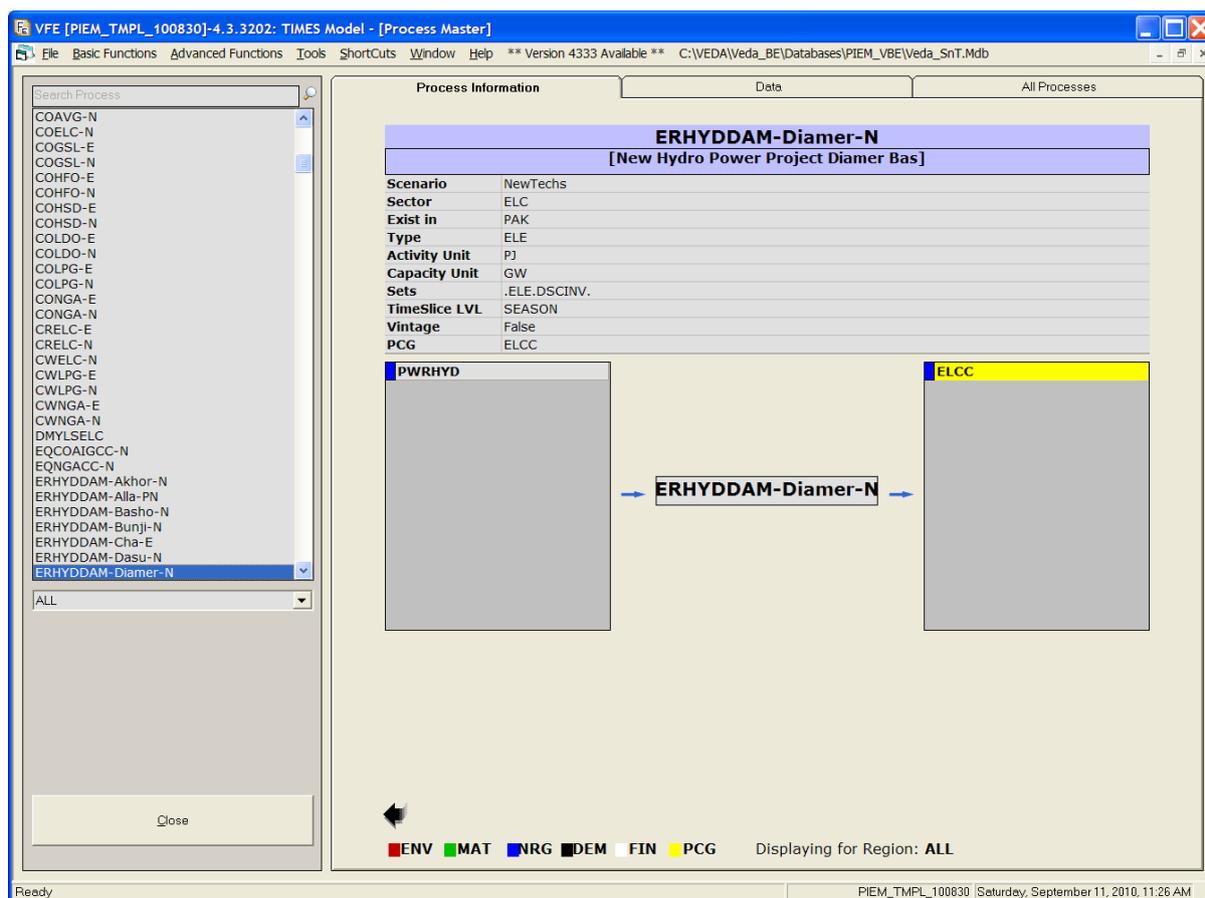


Figure 26: VFE Process Master

3.2. RES Network Diagramming

The most intuitive way to view the underlying interconnections that describe the energy system being modeled is by means of the Reference Energy System (RES) network diagramming facility of VFE, shown in Figure 27. The RES example shows the Diamer power plant, which consumes water (PWRHYD) and produces central station electricity (ELCC). The process box and commodities are color coded according to the main group to which it belongs. The RES form also displays the User Constraints (UCs) relevant to that component, and optionally the associated data cube (for editing if desired).

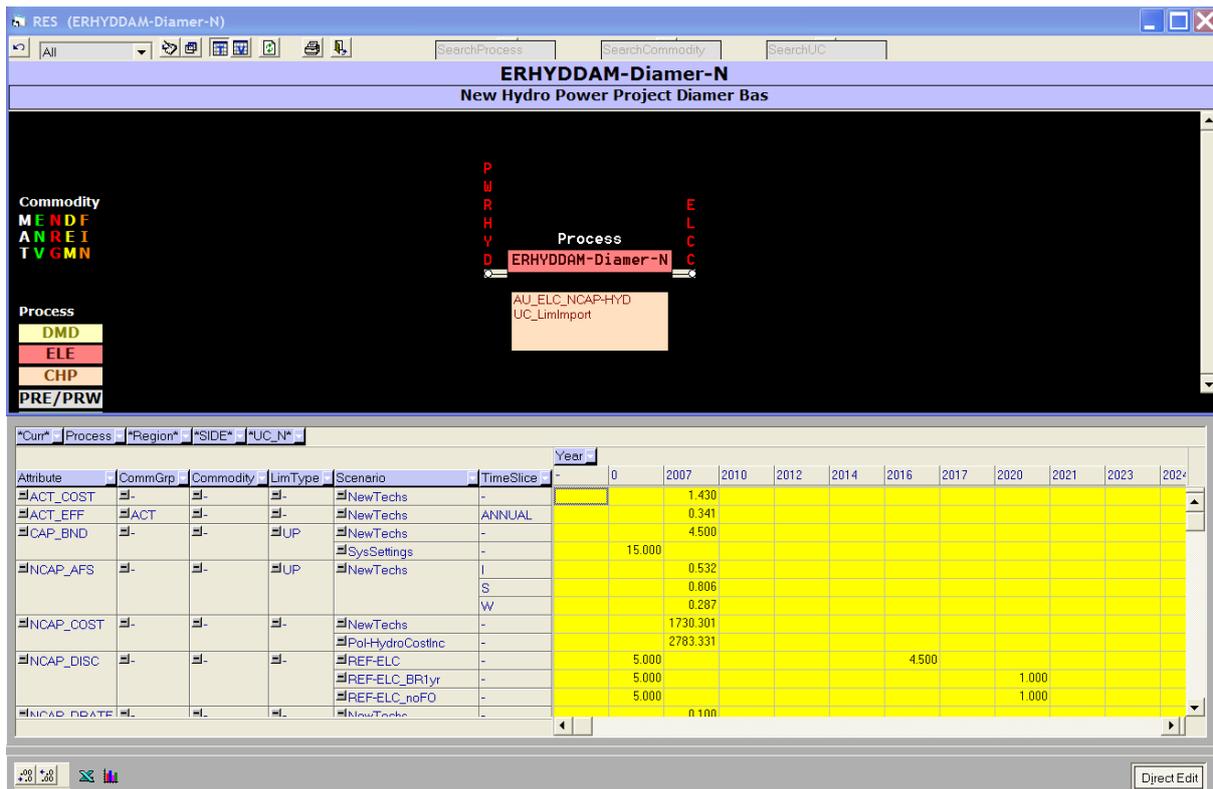


Figure 27: VFE RES Network Diagram and Data - Process View

Clicking on any of the entities on the RES (that is process, commodity, UC) will bring that element into focus, where in Figure 28 we clicked in PWRHYD to jump from the power plant view to see all the hydro electric facilities, turning off the cube display. One may also control access by typing the name of the desired process/commodity into the associated selection box up at the top of the RES form (where PWRHYD is displayed). This is where one also finds the data view toggle (for TIMES and VEDA) by pressing the T/V spread icons at the top of the RES form.

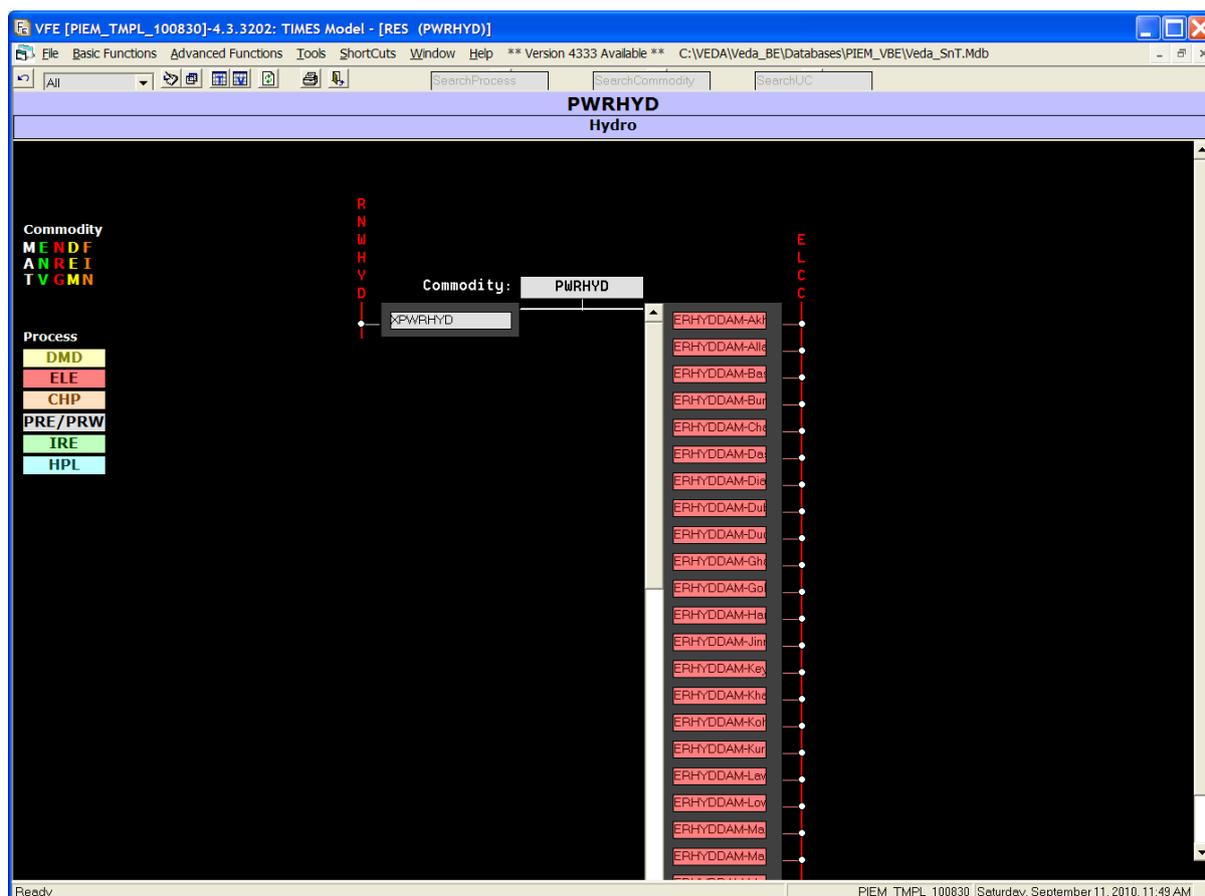


Figure 28: VFE RES Network Diagram - Commodity View

4. Managing Demand Projections

VEDA manages the projection of future demand for energy services by apply Drivers and shaping Series to the base year demand levels established as part of model calibration. The user must provide the various Drivers and Series via the Demand workbook templates, as well as indicate which Driver and Series is to be applied to each demand to produce the associated extrapolation of the base year demand out over time.

The data templates themselves can be accessed just like any other template via the VFE-Navigator. However for visualizing, comparing and adjusting the demands the VFE Demand Master (under the Advanced menu) may be used. The Demand Master supports:

1. **Demand Manager** – providing an indication of the Driver, primary (calibration) and secondary (sensitivity) series applied to shape the demand
2. **View/Edit a Single Demand** – to see and adjust the individual series affecting the evolution of a demand
3. **View/Compare Multiple Demands** – to see several demand projections side-by-side
4. **Viewing/Compare Drivers** – to see the main drives applied to the various demands side-by-side

For Pak-IEM, the VFE Demand Module facilities are very useful for viewing the demand projections and components thereof. However, changes to these should be done directly in the templates as the final Drivers are built-up from a series of calculations, as discussed in Section II.C.6. The one exception is that changes in the allocation of Drivers/Series to

demands can be done via the Demand Manager, as shown in Figure 29, by means of the pull-down lists which are populated from the *Dem_Alloc+Series* template. [Note that currently only a single Series = 1 is used for Pak-IEM, because no shaping of the demand drivers is done via these functions. Instead, the Pak-IEM demands are built in the Demand template.]

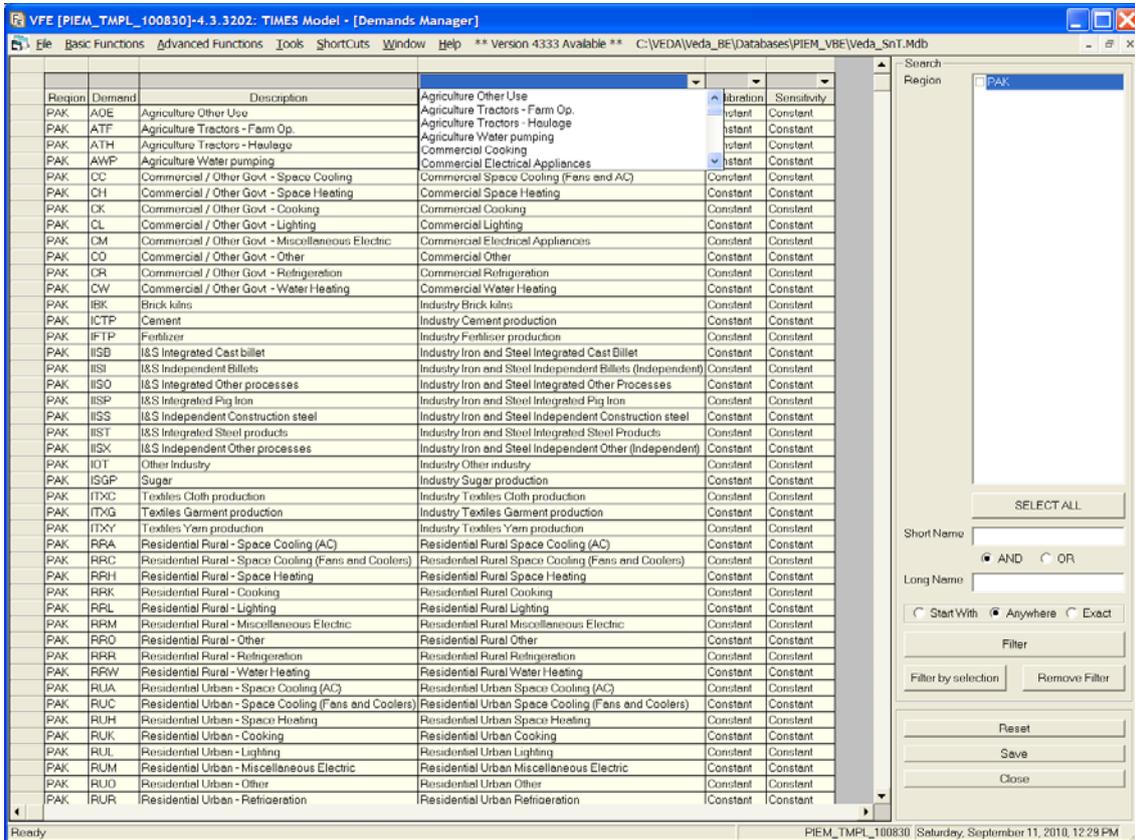


Figure 29: VFE Demand Master – Driver and Series Allocation

This is not to say that the other Demand Manager features are not useful. In particular the demand and driver comparison viewing facilities, shown in Figure 30 for the former, can be quite insightful by allowing the various projections to be compared. This figure actually displays the relative growth of each of the demands (not their absolute level passed to the model) showing that the air conditioning and refrigerator demands are growing much faster than the others.

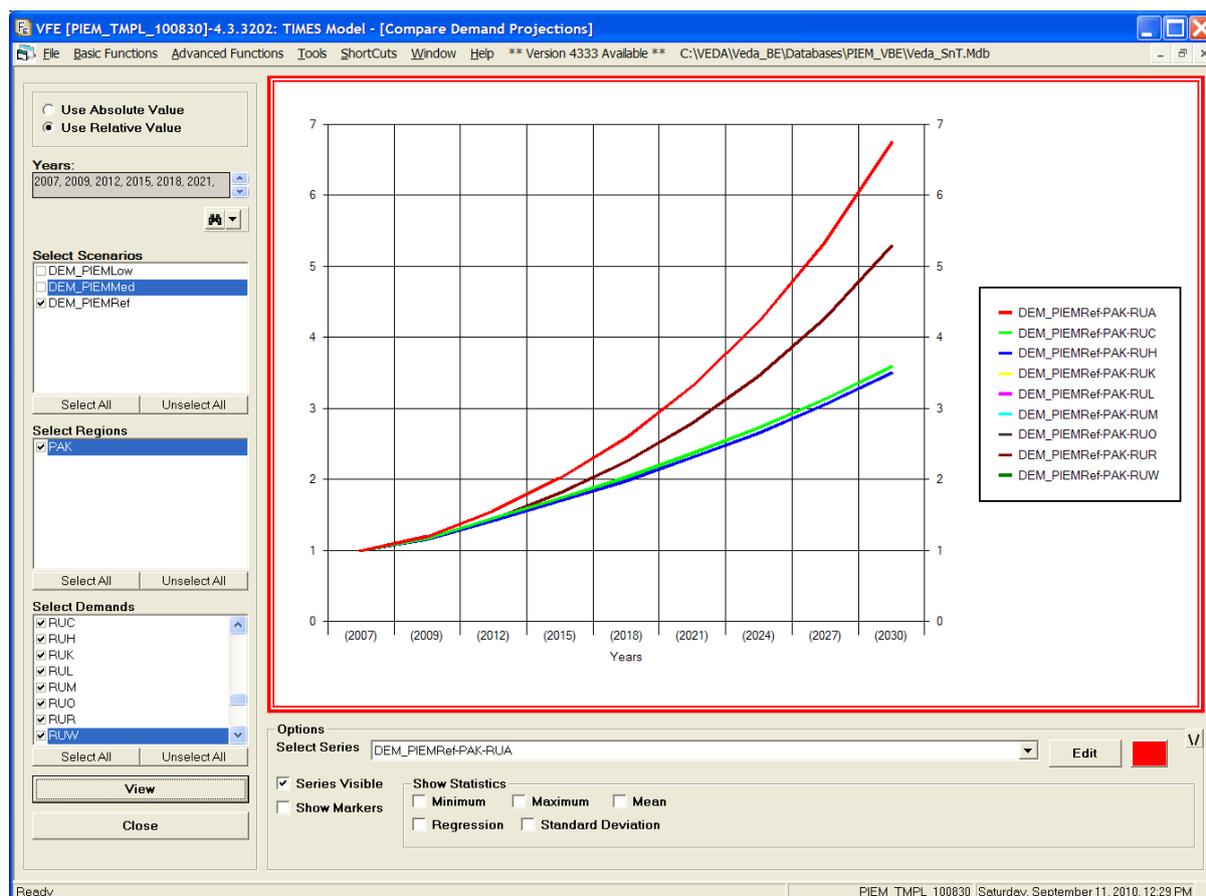


Figure 30: VFE Demand Master – Comparison of Relative Demand Growth

5. Other VFE/TIMES Features

Some other aspects of VFE and TIMES are also good to know and therefore discussed here.

- Commodity Groups and Process Normalization** – Pak-IEM relies on VFE to construct all the Commodity Groups required by TIMES. Commodity Groups serve two purposes – they provide an indication of whether a process is input or output normalized and which group of commodities (including a single one) is used to define the operational characterization of the process. The TIMES/VEDA default for the normalization is output, which is what is used throughout Pak-IEM, with one exception being the refineries. Refineries are input normalized as the size (capacity and thereby associated costs (investment and fixed O&M) are based on the barrels of crude that can be handled. As to Commodity Groups, they are automatically assumed to be “all of the like flows out” (or “in” in the case of refineries) of a process. Like flows are all those flows of the same commodity type (e.g., NRG, MAT, DEM) leaving (entering) the process. The Primary Commodity Group (PCG) is used to define whether a process is input or output normalized. The PCG can be identified in the Process Master, see Figure 31, as the outputs (or inputs) with yellow color code. *{As most Pak-IEM processes only have a single input/output, each commodity is its own Commodity Group, and the Commodity Group Advanced Function is not used much for Pak-IEM.}*

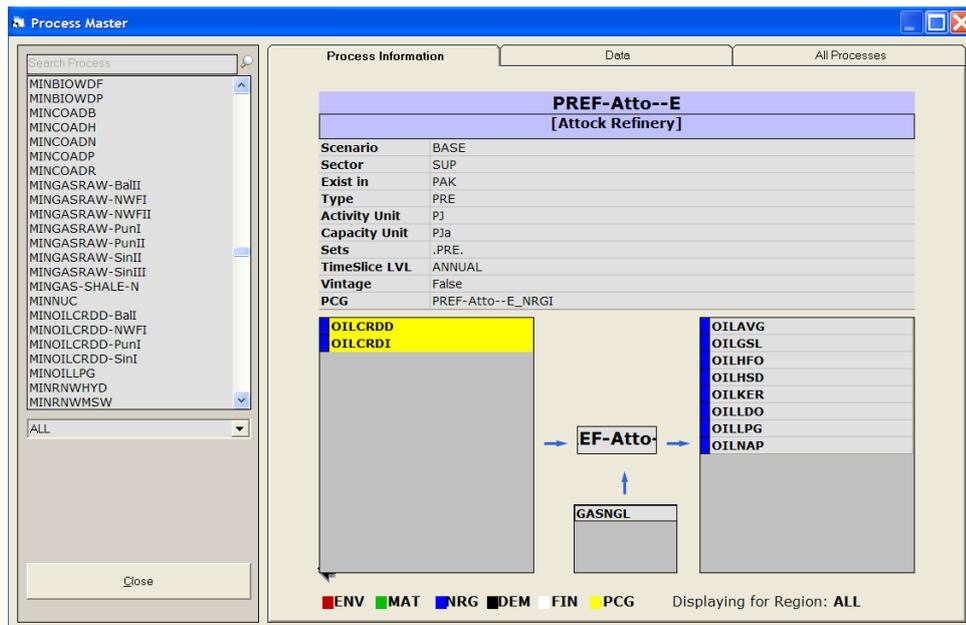


Figure 31: Primary Commodity Group Identification

- Milestone Years** – These are the years for which the model is run. Since TIMES supports full independence of data year and model years there can be any number of run period series specified by the user. Milestone Year series can be constructed using the option on the Advanced Functions menu. To do so one simply indicates in Col-A of the Milestone Year form, shown in Figure 32, the number of years to be assigned to each period, then VFE determines what the associated start/middle/end year is. The main Pak-IEM Milestone Years used for the production runs is the PIEMMSY series shown in the figure.

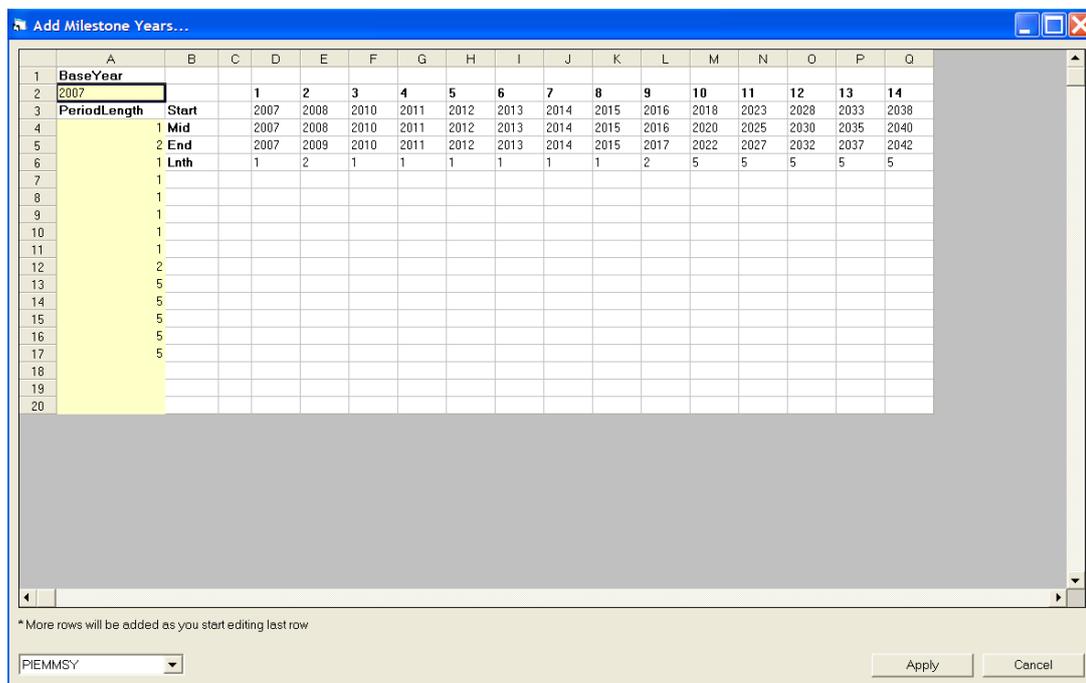


Figure 32: VFE Milestone Year Manager

- User Options** – This command under the Tools menu presents a series of forms for customizing aspects of VFE. The General form should appear as shown in Figure 33. In particular, the Climate Parameters should be unchecked. (Otherwise, you'll see spurious commodities for non-GHG emission tracking and such). The File Locations form, shown in Figure 34, is where one connects VFE with an associated VBE database so that the Sets defined in the latter can be used by the former. Once this is done the VBE SnT will appear on the top line of the VFE form. The third form presents the import options. Here the user can instruct VFE to do or not do certain quality control (QC) checks, establish or not "dummy" imports for each commodity as a means for avoiding infeasibilities during model runs, and whether or not to automatically generate bounds according to vintage. [Not relevant to Pak-IEM.] *{It is recommended that for Pak-IEM the settings remain as shown below.}* If you are experiencing a problem with your model run where GAMS terminates unexpected with an error=13, this may be because your virus protection software is not allowing temporary files with the extension .SCR to be created. Checking the Use srcext-TMP switch, as shown in Figure 33, will get around this.

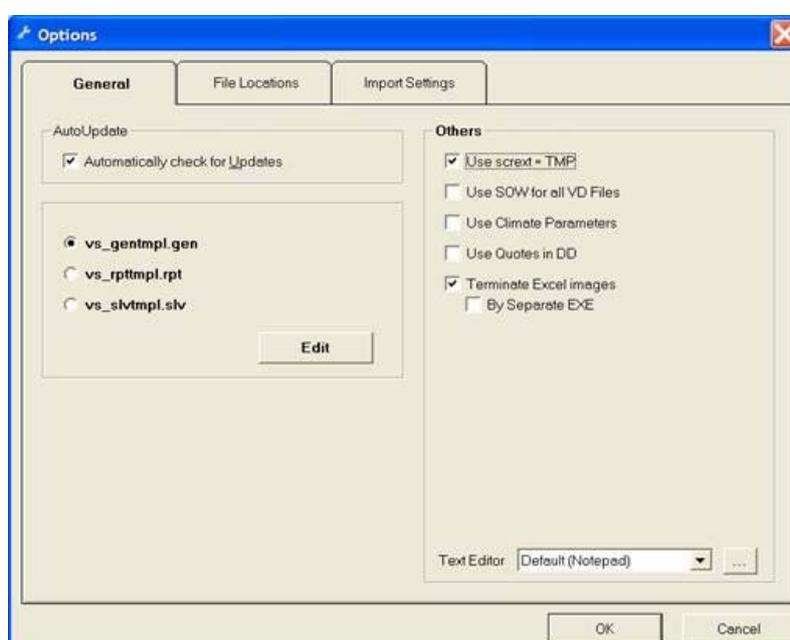


Figure 33: VFE User Options – General

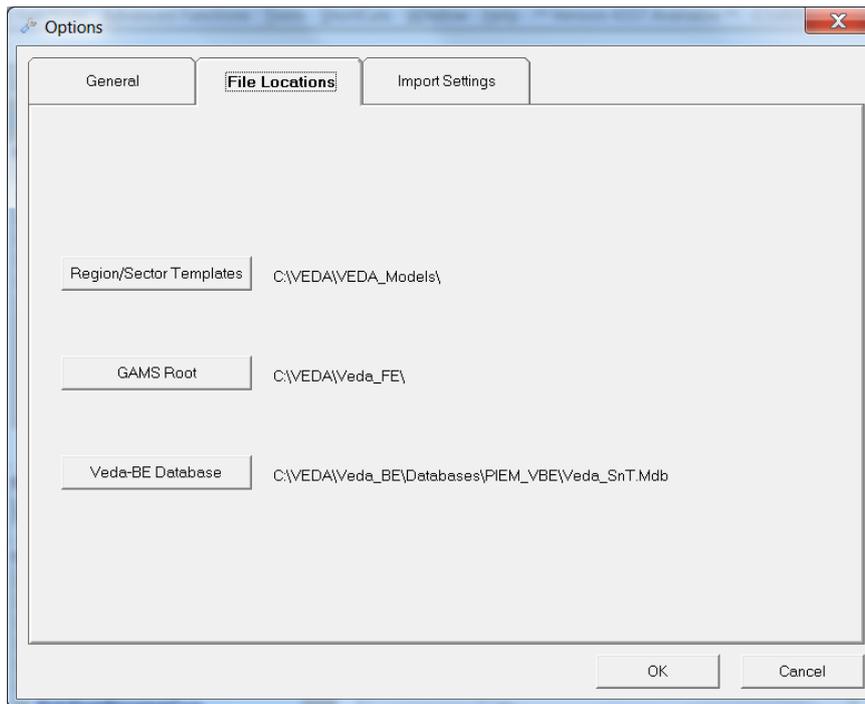


Figure 34: VFE User Options – File Locations

- Model Stats** – This command under the Tools menu presents a snapshot of the underlying components of a model. Specifically, it provides a count of the various processes and commodities by sector, split between the BY/NewTech, along with the UCs by scenario. The current Pak-IEM stats are shown in Figure 35.

The 'Model Stats' window displays a table with the following data:

Item	Scenario	Region	Type	AGR	COM	ELC	IND	RSD	SUP	TRN	
Commodity	BASE	PAK	DEM	4	8		15	18		12	
			ENV	3	2	3	2	2	8	2	
			MAT				7		2		
			NRG	4	9	13	40	13	31	7	
	NewTechs	PAK	ENV				1				
			MAT				3				
NRG									5		
Process	BASE	PAK	CHP					2			
			DMD	9	20		14	38		18	
			ELE			57	7				
			IRE	3						51	
			PRE	13	24	11	45	36	9	9	
	NewTechs	PAK	CHP				3				
			DMD	11	23		18	84		38	
			ELE			77	8				
			IRE				3			10	
UserConstr	Pol-BudgetLimit	PAK	UP	1							
	Pol-CO2Tax	PAK	UP	7							
	Pol-EnEfficiency	PAK	UP	1							
	Pol-ImportDependency	PAK	UP	1							
	Pol-NuclearForceCum	PAK	UP	1							
	Pol-Pak	Pak	LO	1							
	Pol-RenElecPotential	PAK	UP	10							

Figure 35: VFE Model Stats Count

- **Export Scenario Data to VBE** – This command under the Tools menu permits the data associated with any scenario to be exported to VBE for analysis. *{Since the VFE Browse allows scenario data be freely manipulated, and the resulting cube exported (via right-mouse) to Excel, this feature is not used very often.}*
- **Close all XLS** – This command under the Tools menu can be useful when there seems to be a conflict between Excel and VFE when accessing templates. *{This feature is rarely used}*.
- **Start from Scratch** – This command under the Tools menu can be used to rebuild the internal VFE database from the templates. This is sometimes desirable when moving the model between computers, and is the first operation to try when VFE does not seem to be performing properly.
- **ShortCuts** – This menu allows for switching between windows or tailoring of the information currently displayed in the Navigator window. *{These commands are rarely used}*.
- **Windows** – This menu contains the Refresh command and allows the User to move back to the Navigator from other currently open windows.

IV. Running Pak-IEM

The process of running Pak-IEM is overseen by the VFE Case Manager, which will be described in the first section below. There are three basic categories of model runs: confirmation of the base (first) year calibration against the Energy Balance, tailoring and establishing the Reference Scenario, and conducting sensitivity analyses. Each of these are discussed in the following sections.

A. Case Manager

The process of running Pak-IEM consists of using the VFE Case Manager (shown in Figure 36) to ensure that the run environment is properly set up, compose the scenarios comprising the run, name and submit the model run, and do troubleshooting if problems are encountered during a model run. The various quadrants and tabs of the Case Manager form oversee each of the activities, as discussed in the following sections.

Note that the letter/color coding alongside the various scenario names correspond to the group indicators displayed on the VFE-Navigator form, as discussed previously.

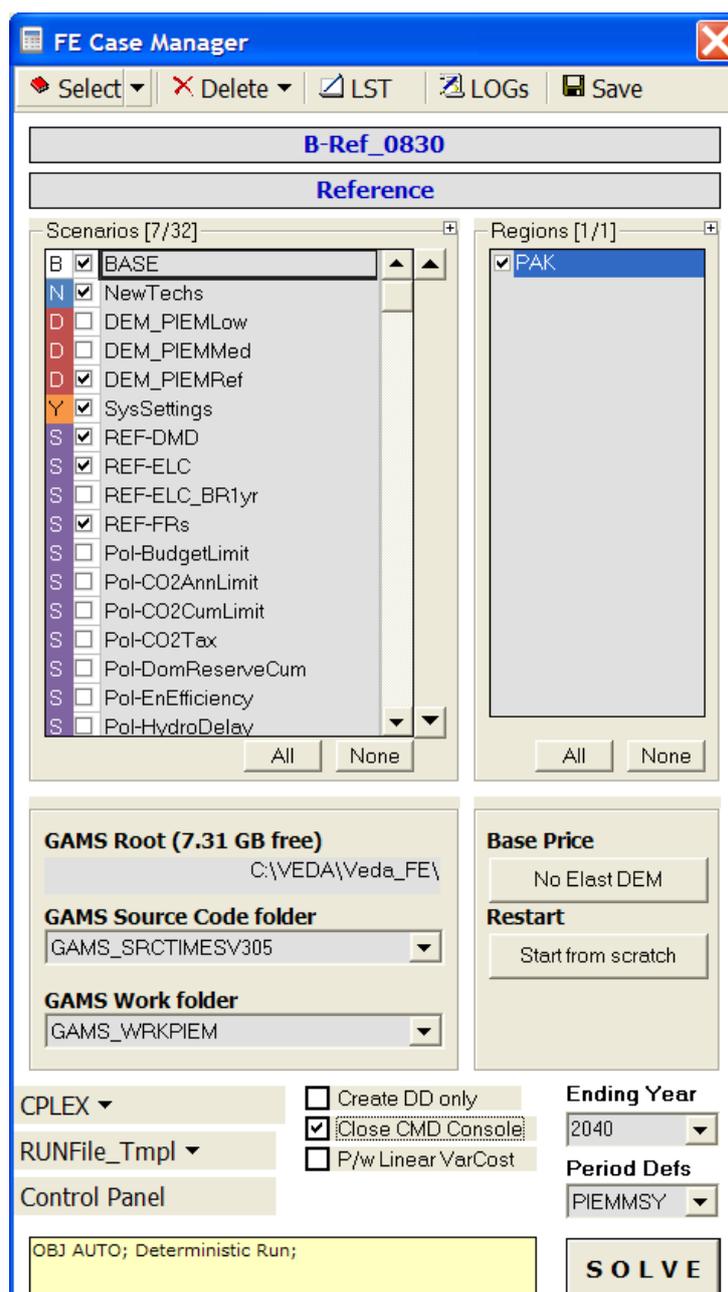


Figure 36: VFE Case Manager

1. Run Environment

The run environment, which is the lower left portion of the Case Manager, informs VEDA of:

- GAMS Root – is the folder under which the GAMS source and work folders reside [it can be set via the Tools/Options/File Location menu, but should not need to be adjusted for PIEM]
- GAMS Source Code Folder - which version of the TIMES Source Code is to be used [this should always be the latest GAMS_SrcTIMESv## folder];
- GAMS Work Folder - the folder in which the model is to be run and all GAMS output files saved [this should always be the GAMS_WrkPIEM folder]

- CPLEX – the solver control file that is to be used [this should always be CPLEX or OTHER when using a custom control file.].
- RUNFile - the instance of the Run File template that is to be used [should not need to be adjusted for PIEM].
- Control Panel – see explanation below.
- Create DD only – to generate out the model input data but not start the GAMS run to save the model (rarely used).
- Close CMD Console – for each run you can either automatically have the Command Prompt window closed, or leave it open if you want to say compare the objective function value for successive runs.
- P/w Linear VarCost – this piecewise linear interpolation feature is only used with very large models and is not relevant to Pak-IEM.
- Ending year – the model run horizon can be shortened to a period prior to the last year in the Period Definition.
- Period Defs – the Period Definition (model run years) to be used [this is changeable to any of those pre-defined sets created via VFE\Advanced\Milestone Year facility and appearing in SysSettings(TimePeriods)].

While almost everything regarding the run environment has been set up and likely will not need to be changed (e.g., CPLEX options file), a brief explanation of the Control Panel settings (Figure 37) as it relates to Discrete/Lumpy Investments is warranted (for the rest see VedaSupport). The Control Panel allows for TIMES switches to be adjusted to activate/deactivate various model variants and options. For the most part these settings can be left as is, with the user referred to the VedaSupport site for more information on the various TIMES switches. However, there is one instance when the Pak-IEM analyst may need to adjust the Control Panel settings. As is discussed in Section III.C, Pak-IEM employs the lumpy investment facility in TIMES to handle discrete build/no-build choices for such things as large power plants and infrastructure investments (e.g., pipelines, transmission lines, LNG terminals, coal mines). The TIMES implementation of this feature requires that a mixed integer (MIP), rather than LP problem be formulated and solved. Beside requiring the appropriate input data, the MIP options need to be activated for VEDA and CPLEX. This is done by checking the Discrete Investment TIMES Extensions option (upper right corner) and providing a value of OPTCR=0 in GAMS Option (lower left corner) to ensure zero tolerance on the MIP solve, as shown in Figure 37. [But MIP is demanding requiring additional model solve time, so as the model grows during debugging runs one may want to either turn off the Discrete Investment switch, or loosen the OPTCR value to 0.001 or so.] *{Note also that when updating VEDA the TIMES Extension Climate Module is often activated, but Pak-IEM does not require this feature, and it should always be unchecked.}*

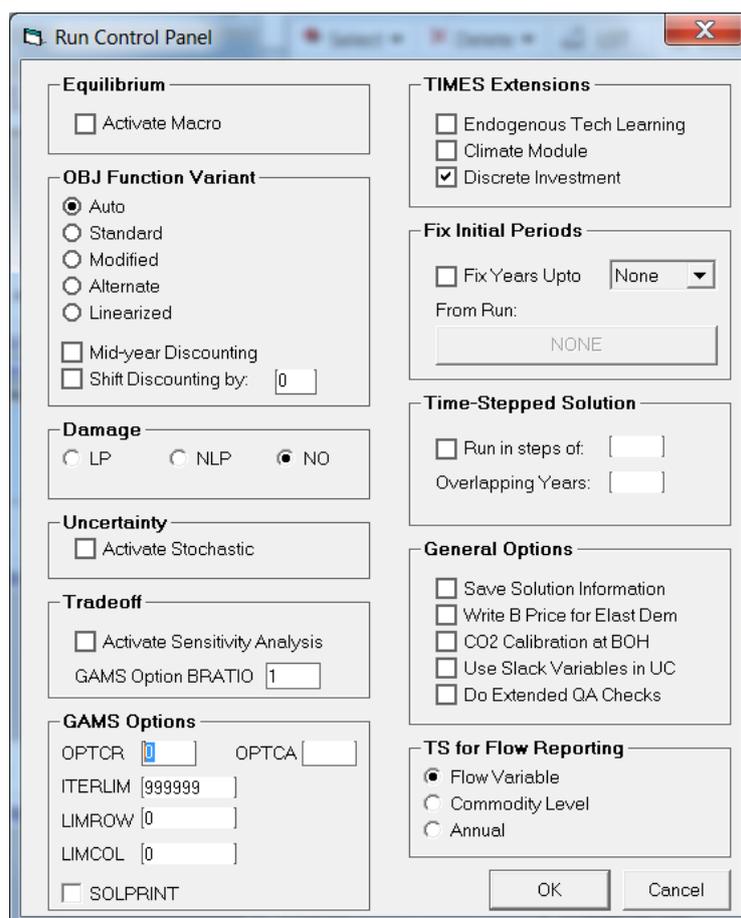


Figure 37: Run Control Panel

The other GAMS Options that are useful at times are to set LIMROW/LIMCOL if you want to see the equation/column listing in the LST file (the number you set will be the number of equations/columns listed for each one), or check the SOLPRINT switch if you want to see the solution dump.

The last run control setting that needs to be specified is the Milestone (run) years, Period Defs, which are to be used for the model run. Pak-IEM has predefined run periods. The setting of Milestone years was discussed in Section III.A.5. For Pak-IEM there are three main Milestone years established, where the start/middle(of the period)/end/length for each are shown in Figure 38. The Milestone year list used most often is PIEMMYS, which corresponds to the periods found in the Analytics Workbook, as discussed in Section V.D.

In addition, failing to properly sequence the scenarios for a model run may result in GAMS domain violation warnings (\$170s, as shown in the LST file – Figure 39), which is an indication that some items are not defined when initially read because they are defined in scenarios further down in the sequence.

```

B-Ref_0621-03g-2 - Notepad
File Edit Format View Help
GAMS Rev 233 WEX-WEI 23.3.3 x86_64/MS Windows 0
TIMES -- VERSION 4.1.0
C o m p i l a t i o n

2 OPTION RESLIM=50000, PROFILE=1, SOLVEOPT=REPLACE;
3 OPTION OPTCR=0, ITERLIM=999999, LIMROW=0, LIMCOL=0, SOLPRINT=OFF;
4
5 option LP=cplex;
6
7 *--If you want to use an optimizer other than cplex/xpress, enter it here:
8 *OPTION LP=MyOptimizer;
9
GAMS Rev 233 WEX-WEI 23.3.3 x86_64/MS Windows 0
TIMES -- VERSION 3.0.2
C o m p i l a t i o n

9203 PAK.0.PREF-Bosi-PN.ANNUAL.UP 15
**** $170
**** LINE 30 BATTINCLUDE C:\VEDA\Veda_FE\GAMS_WRKPIEM\SYSSETTINGS.dd
**** LINE 73 INPUT C:\VEDA\Veda_FE\GAMS_WRKPIEM\B-Ref_0621-03g-2.RUN
9204 PAK.0.PREF-Khal-PN.ANNUAL.UP 15
**** $170
**** LINE 31 BATTINCLUDE C:\VEDA\Veda_FE\GAMS_WRKPIEM\SYSSETTINGS.dd
**** LINE 73 INPUT C:\VEDA\Veda_FE\GAMS_WRKPIEM\B-Ref_0621-03g-2.RUN
9205 PAK.0.PREF-Tran-PN.ANNUAL.UP 15
**** $170
**** LINE 32 BATTINCLUDE C:\VEDA\Veda_FE\GAMS_WRKPIEM\SYSSETTINGS.dd
**** LINE 73 INPUT C:\VEDA\Veda_FE\GAMS_WRKPIEM\B-Ref_0621-03g-2.RUN
9220 PAK.0.ERDAMHYD-Akhor-i-N.UP 15
**** $170

```

Figure 39: GAMS LST File

The last decision to be made is the naming of the model run, and its associated description. Keep in mind that VBE will be presenting the scenarios in alphabetic order in the cubes. Thus, it is recommended to impose naming conventions along the lines of *<B/P>-<dem-pol>-<date>-<i>*, where *<B/P>* is for Base/Policy, *<dem>* is Demand Scenario, *<pol>* is policy scenario, *<date>* is the date for the run series, and *<i>* is an index counter or designator as needed (e.g., B-Ref_0621-03 for Base, Reference demand, no policy, run on 6/21, third iteration of this run). It is important to keep in mind that model runs in VBE will be sorted by the run name, and so following conventions along these lines will help to keep like runs grouped together and such. The description should follow similar principles (e.g., Reference/Low/High - Policies and qualifiers). [These are suggestions, as VEDA/TIMES do not impose any limitation, but they are very helpful for keeping your runs organized and clear.]

With all parameters and scenarios now set, clicking the SOLVE button will open a Command Prompt window along the lines shown in Figure 40 echoing the GAMS model preparation and solve. Upon completion of the run VFE will report the status. If a problem arises the areas discussed in the next two sections should help.

```

C:\WINDOWS\system32\cmd.exe
--- .....cal_caps.mod(26) 7 Mb
--- .....rpt_obj.rpt(125) 7 Mb
--- .....rpt_objc.rpt(106) 7 Mb
--- .....rpt_obj.rpt(125) 7 Mb
--- .....rptlite.rpt(160) 7 Mb
--- .....cost_ann.rpt(171) 7 Mb
--- .....cal_caps.mod(26) 7 Mb
--- .....cost_ann.rpt(176) 7 Mb
--- .....cal_caps.mod(26) 7 Mb
--- .....cost_ann.rpt(224) 7 Mb
--- .....rptlite.rpt(347) 7 Mb
--- ..rptmain.mod(47) 7 Mb
--- ..solsetv.v3(194) 7 Mb
--- ..rptmain.mod(51) 7 Mb
--- ..maindrv.mod(111) 7 Mb
--- ..main_ext.mod(15) 7 Mb
--- ..maindrv.mod(119) 7 Mb
--- ..err_stat.mod(55) 7 Mb
--- ..maindrv.mod(120) 7 Mb
--- ..err_stat.mod(55) 7 Mb
--- ..maindrv.mod(124) 7 Mb
--- B-Ref_0621-03g-2.RUN(97) 7 Mb
*** 379 Warnings - check listing
--- B-Ref_0621-03g-2.RUN(97) 8 Mb
--- Starting execution: elapsed 0:00:01.594

C:\WINDOWS\system32\cmd.exe
Dual: Pushed 6883, exchanged 2743.
Using devex.

Iteration log . . .
Iteration: 1 Objective = 189769445.725638
Total crossover time = 1.09 sec.

Total real time on 2 threads = 12.69 sec.
Fixed MIP status(1): optimal

Proven optimal solution.

MIP Solution: 189769445.725127 (135 iterations, 0 nodes)
Final Solve: 189769445.725125 (44 iterations)

Best possible: 189769445.725127
Absolute gap: 0.000000
Relative gap: 0.000000

--- Restarting execution
--- B-Ref_0621-03g-2.RUN(53698) 27 Mb
--- Reading solution for model TIMES
***
*** Reading with solevopt=REPLACE (0)
***

```

Figure 40: GAMS Command Prompt Window

3. Managing Cases

Besides the core function of setting up and running a model, the Case Manager also assists with keeping track of the model runs so that previous runs can be recalled, and the GAMS list (LST) or TIMES quality control Log examined, and old cases deleted. Clicking the LST Files tab at the top of the Case Manager will bring up a list of runs. Check the one desired and click OK to open the file. A similar process works for LOG Files and Del Cases, where for the latter one can have input and result files deleted if desired. The Close button next to OK returns the user to the main Case Manager form. The LST and LOG files are discussed further in the next section.

To reload a previous case, go to the All Cases tab (see), check the case you want, and click Load. You can then rerun this case – overwriting the current run, or you can change the case name or version number and rerun the case preserving the previous run results.

In addition to recalling a single model run, from the Select tab you can also submit a series of runs as a Batch by multi-selecting the desired runs and clicking the Batch Solve button at the bottom left of the form. Moreover, you can save a group of runs, giving the batch a name, by clicking the save icon at the bottom right, which is then available to be recalled to resubmit said group of runs. This is handy when you have a bunch of runs to do over lunch/night! See Figure 41.

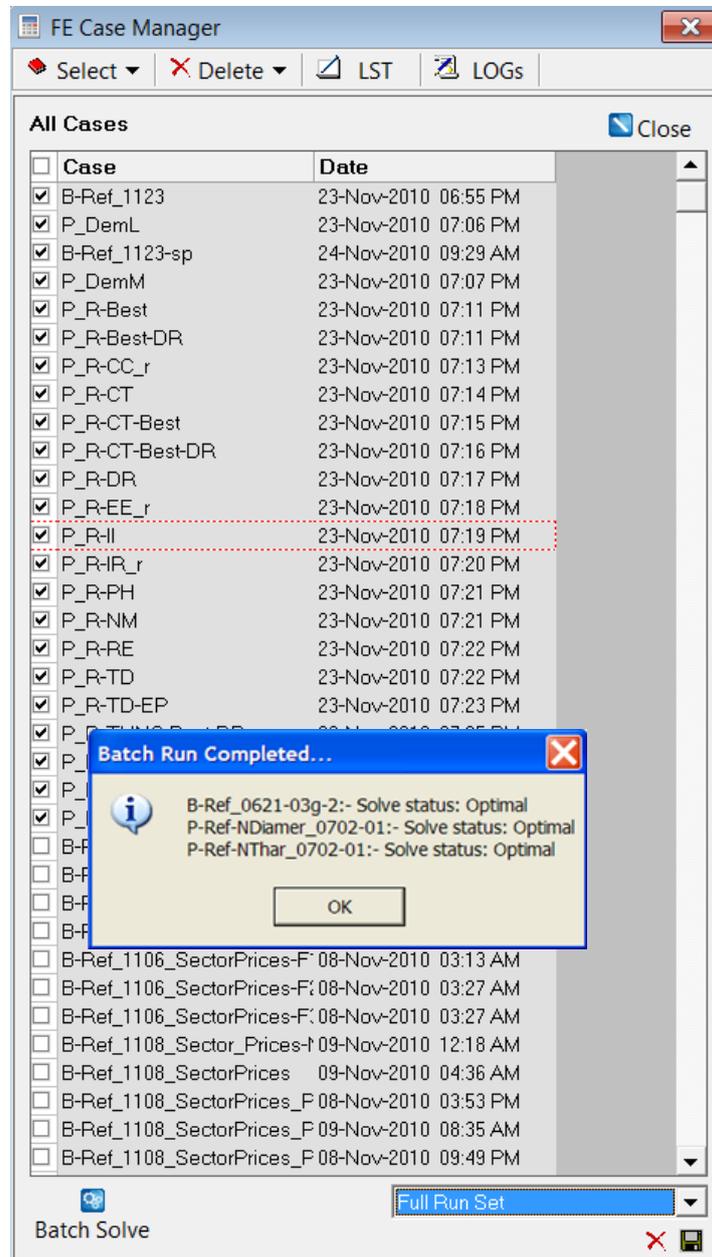


Figure 41: VFE Case Manager - Batch Run

4. Troubleshooting

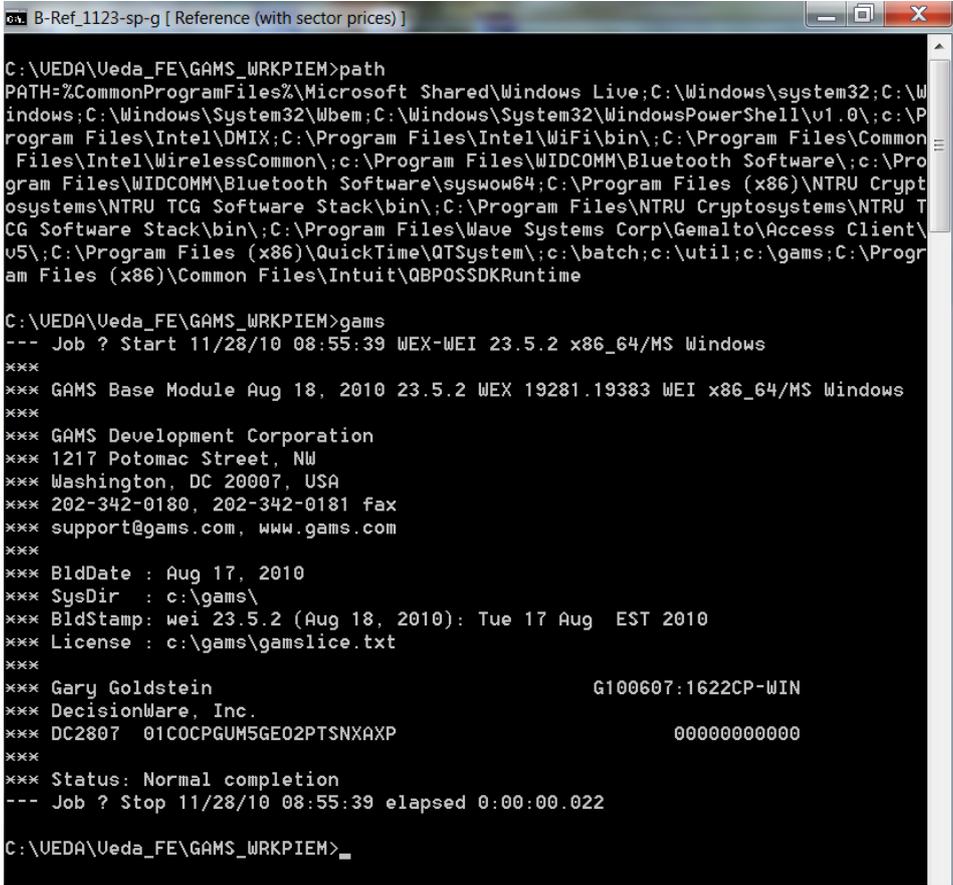
There are three areas where problems may arise when working with VEDA and TIMES – (setup, SYNCing, and solving – some aspects of which have already been discussed in Section III.A.1 and the next sections.

4.1. Setting Up the VEDA/GAMS Environment

The VedaSupport website <http://www.kanors.com/VedaSupport/index.htm> provides clear instructions for installing and configuring VEDA. Two areas where there are sometimes problems relate to installing VEDA in the <drive>:\VEDA folder (recommended that the installation of VEDA be done from the same folder) and properly setting the GAMS path to enable VEDA and GAMS to "talk" as part of submitting model runs.

If the VEDA installation encounters problems and installation was done in other than the \VEDA root folder it is recommended that VEDA be uninstalled/re-installed properly.

If the GAMS path is not properly established then when the VFE-CaseManager submits a run and the Command Prompt window opens, an error message will be presented, indicating that GAMS is "not found" and the run terminates. From the Command Prompt you can double-check the path setting and GAMS connection by typing PATH to see the Windows path in effect, and the typing GAMS to have your GAMSLICE license file details echoed, as shown below, if the path is setup properly.



```

C:\VEDA\Ueda_FE\GAMS_WRKPIEM>path
PATH=%CommonProgramFiles%\Microsoft Shared\Windows Live;C:\Windows\system32;C:\Windows;C:\Windows\System32\Wbem;C:\Windows\System32\WindowsPowerShell\v1.0\;c:\Program Files\Intel\DMIX;C:\Program Files\Intel\WiFi\bin\;C:\Program Files\Common Files\Intel\WirelessCommon\;c:\Program Files\WIDCOMM\Bluetooth Software\;c:\Program Files\WIDCOMM\Bluetooth Software\sylwowl64;C:\Program Files (x86)\NTRU Cryptosystems\NTRU TCG Software Stack\bin\;C:\Program Files\NTRU Cryptosystems\NTRU TCG Software Stack\bin\;C:\Program Files\Wave Systems Corp\Gemalto\Access Client\U5\;C:\Program Files (x86)\QuickTime\QTSystem\;c:\batch;c:\util;c:\gams;C:\Program Files (x86)\Common Files\Intuit\QBPOSSDKRuntime

C:\VEDA\Ueda_FE\GAMS_WRKPIEM>gams
--- Job ? Start 11/28/10 08:55:39 WEX-WEI 23.5.2 x86_64/MS Windows
***
*** GAMS Base Module Aug 18, 2010 23.5.2 WEX 19281.19383 WEI x86_64/MS Windows
***
*** GAMS Development Corporation
*** 1217 Potomac Street, NW
*** Washington, DC 20007, USA
*** 202-342-0180, 202-342-0181 fax
*** support@gams.com, www.gams.com
***
*** BldDate : Aug 17, 2010
*** SysDir : c:\gams\
*** BldStamp: wei 23.5.2 (Aug 18, 2010): Tue 17 Aug EST 2010
*** License : c:\gams\gamslice.txt
***
*** Gary Goldstein G100607:1622CP-WIN
*** DecisionWare, Inc.
*** DC2807 01C0CPGUM5GE02PTSNXAXP 000000000000
***
*** Status: Normal completion
--- Job ? Stop 11/28/10 08:55:39 elapsed 0:00:00.022

C:\VEDA\Ueda_FE\GAMS_WRKPIEM>_

```

Figure 42: Checking the GAMS Path

Again, detailed instructions for installing VEDA can be found on the VedaSupport site. If problems persist, let IRG or KanORS know.

4.2. Setting Up the Pak-IEM Environment

As discussed in Section II.A, Pak-IEM needs to be installed in specific folders, and VFE needs to be connected to VBE. The model input data templates are contained within the PIEM_TMPL_<date> folder and sub-templates residing under the \VEDA\VEDA_FE\VEDA_Models folder. The associated Pak-IEM model results are kept in a

PIEM_VBE folder that resides under the \VEDA\VEDA_BE\Databases folder. In order for VFE to share VBE user-defined Sets via the VFE Options/File Location menu the PIEM_VBE folder needs to be connected, then appearing on the top line of the VFE menu line. Note that if this connection is not active then the list of sets available via VFE-Browse will not include the suite of PIEM_VBE sets and, more critically, VBE sets used in any of the Scenario files will not be recognized during the SYNC operation (see Figure 22).

The other setup issue that may be encountered is that in order for VBE to see the model results associated with each run the VFE CaseManager GAMS Work Folder (either GAMS_WrkTIMES or GAMS_WrkPIEM) must coincide with the VBE Import folder handled via the Manage Import File Locations option, as shown below.

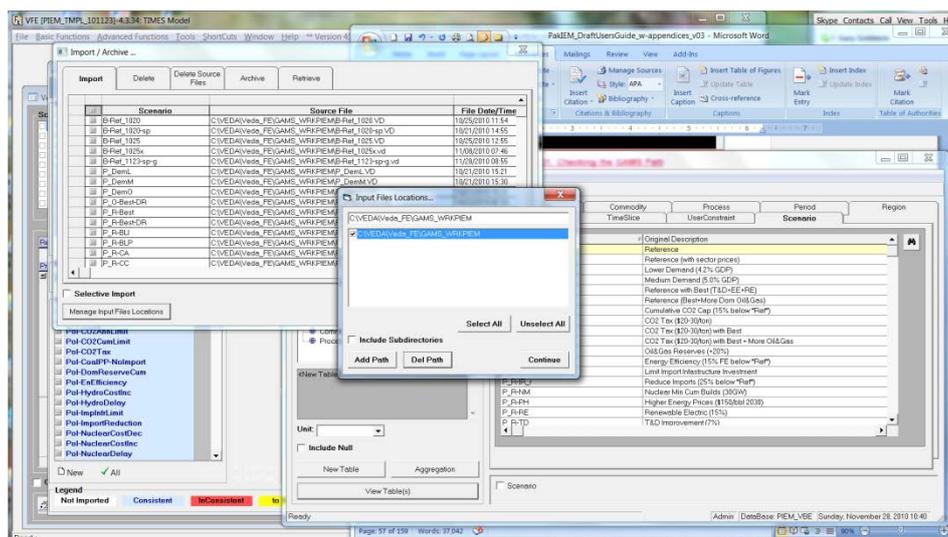


Figure 43: Connecting VBE Results Import with VFE Run Folder

4.3. VFE-Navigator SYNC Problems

As discussed in Section III.A.1 during the VFE-Navigator SYNC process, several problems could arise in importing the changed templates and update the VFE database,. The most common of these can include:

- Sets not being recognized (often due to the PIEM_VBE not being connected to VFE, as just discussed in the previous section)
- Unrecognized attributes in a table (usually a typo)
- VFE UPD/INS conflict
- Commodity in/out of a process not know (usually a missing declaration or typo)
- Excel "crash" message

VFE-Navigator does a rather good job of identifying, presenting, and connecting to the first two types of errors, but simply reports the third and leaves you to determine if an omission or typo is the problem. Below is an example of the VFE-Navigator error log and the associated problem for an update request for the "X*ELC*" processes to set an upper bound. But, since the ACT_BND(UP) was never provided for these technologies, the ~TFM_INS VFE option must be used to insert a new value, not the ~TFM_UPD option to update an existing entry.

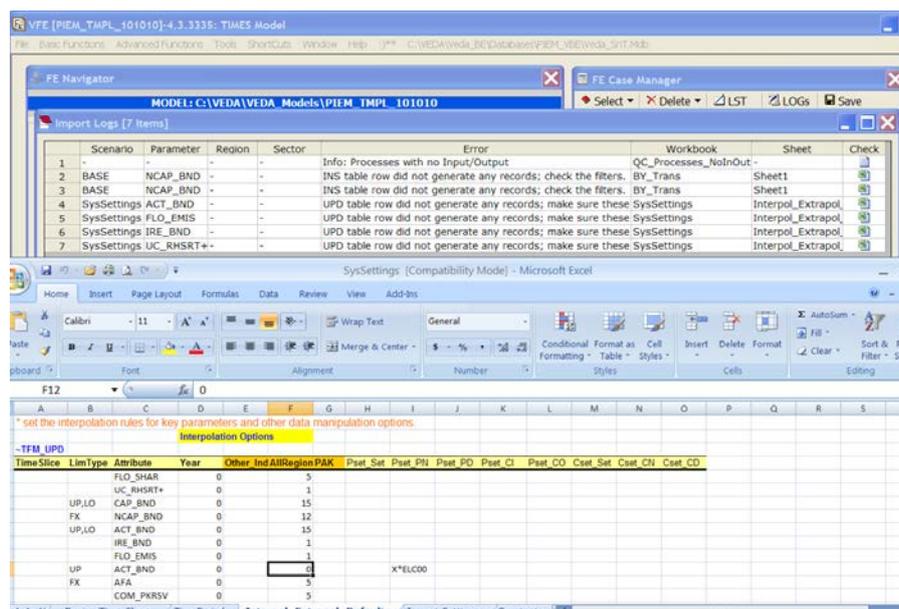


Figure 44: Update/Insert Conflict

The “Excel crash” only occurs on certain computers and remains a mystery in terms of the cause/remedy. For now, simply continue to uncheck restart and continue, the only problem being the annoyance of having to repeatedly do so, necessitating remaining at the computer during the SYNC process.

4.4. Runtime GAMS or Solver Errors

Normally the linkage between VEDA/GAMS will operate smoothly once properly set up. However, there are a few instances when something could go wrong during a model run. These basically fall into two categories – compilation errors (\$170s, as shown in the LST file – Figure 39) or an inability to actually solve the model due to inconsistencies in the model specification. As noted in the previous section, this most often occurs if a process is referenced in a Scenario file that is loaded before a SubRES in which it actually declared.

For solver errors, such as infeasibilities, the analyst needs to bring up the GAMS run LST file. The way the Pak-IEM RES has been designed, the so-called backstop ZZDMY commodities will ensure that each energy/demand balance equation can be satisfied. This helps to eliminate the most common infeasibility in optimization models such as TIMES, but it may still be the case that some relationship in the model cannot be adhered to, for example, a lower bound above an upper bound. As shown in Figure 45, the CPLEX infeasibility finder option will identify the first instance of an infeasibility to guide the analyst towards the problem, iteratively as necessary.

```

B-Ref_1123-sp-g0 - Notepad
File Edit Format View Help
Presolve time = 0.13 sec.
#GAMS Rev 235 WEX-WEI 23.5.2 x86_64/MS Windows 11/28/10 10:
TIMES -- VERSION 3.0.7
Solution Report SOLVE TIMES Using LP From line 63419

=1
LP status(4): unbounded or infeasible
=2
=1
Presolve found the problem infeasible or unbounded.
=2
=1
Rerunning with presolve turned off.
=2
Bound infeasibility column 'VAR_NCAP(PAK.2010.ETNGAHFOCC-N)'.
Presolve time = 0.17 sec.
=1
LP status(4): unbounded or infeasible
=2
CPLEX Error 1217: No solution exists.
CPLEX Error 1217: No solution exists.
*** Unable to retrieve Cplex solution.

=4
**** SOLVER STATUS FILE LISTED ABOVE
#GAMS Rev 235 WEX-WEI 23.5.2 x86_64/MS Windows 11/28/10 10:
TIMES -- VERSION 3.0.7
Solution Report SOLVE TIMES Using LP From line 63419

---- 63419 Solve Read TIMES 0.016 0.016 SECS 54 Mb 11/28/10 10:
#GAMS Rev 235 WEX-WEI 23.5.2 x86_64/MS Windows
TIMES -- VERSION 3.0.7
E x e c u t i o n

```

Figure 45: Solver Infeasibility

4.5. Checking the Calibration

The Pak-IEM model has been calibrated so that it reflects the published energy balance in the Energy Year Book 2007. If changes or updates are made to the model BY templates, then the model calibration should be checked. The goal of the calibration is to match the total energy supply, electricity generation, and energy consumption by fuel type across the entire energy system. This calibration is important, particularly because the base year energy service demands derived from the energy balance provide the seed for the demand projection drivers.

Calibration of the model may be checked in *PakIEM_EnergyBalance-2007.xls*, using worksheets *VBE_Tables* and *Calibration*. The first step to perform calibration checks is to output results from the model on energy production and consumption for 2007. This is done directly from VBE, by selecting the Reference case in the global filter, selecting from the menu *Tools/Update Excel File/All Tables* and opening file *PakIEM_EnergyBalance-2007.xls* when prompted.

This updates the tables in the *VBE_Tables* worksheet. Four VBE tables (prefixed “CL”) are used in the update process:

- *CL_EnergyBalance-Consumption* – provides energy consumption data by sector in 2007
- *CL_EnergyBalance-Production* – provides energy production data in 2007
- *CL_Power Plants Consumption* – provides power plant energy consumption data in 2007
- *CL_Electricity Consumption by timeslice* - provides electricity consumption by timeslice and sector in 2007

The tables *CL_EnergyBalance-Consumption* and *CL_EnergyBalance-Production* tables do not exactly represent primary and final energy balances, as they have been built to check model calibration.

The second step is to compare these data with what is published in the Energy Balance. This is done on the *Calibration* worksheet, which contains four calibration comparison tables corresponding to the four key datasets defined by the VBE tables listed above. These comparison tables contain conditional formatting, which has been used to highlight levels of differences between model results and Energy Balance data, with darker colors representing larger differences. The pale green cells with a “C” denote full calibration. The pale yellow cells are very closely calibrated with the difference value (in PJ) indicated in the cell. Green shaded values show instances where model output values are too high, while orange / red values indicate under-reporting.

- **Energy consumption by sector and fuel type.** Currently calibration, as shown in Table 11, shows a -0.3% difference, which is very close.

Table 11: Calibration Table - Energy Consumption by sector and fuel type

Difference checks (in PJ)																Total							
	COAD	COAI	ELC		GASNGA	NUC	OILAVG	OILGSL	OILHFO	OILHSD	OILKER	OILLOO	OILPLG	BIOVDF	BIOVDF	BIODNF	BIODNP	BIDCRF	BIDCRP				
XAGR			-0.34																			-0.3	
XCOM			-1.27			2.94																13	
XELC						-5.84																-5.8	
XIND	C				-1.38	0.42				0	0											-13	
XPSD											-0.04	0										-2.8	
XTRN		-0.02														0	0	0	0	0	0	-0.15	
Total		-0.02	C		-1.59	2.29	-3.15	C	C	C	C	-0.14	-0.03	0	C	C	0.13	C	0	C	C	-4.8	-0.2%

- **Energy production by fuel type.** Calibration difference is only 0.2%, as shown by the screenshot below.

Table 12: Calibration Table - Energy Production by fuel type

Difference checks (in PJ)																	Total							
	COAD	COAI	ELCC	ELCR	GASASS	GASNGA	GASRAW	NUC	OILAVG	OILCRDD	OILCRDI													
ELE				0.13																				
GASPIIP							-3.29																	
IMP			0		0			0	-2.24															
MIN		-0.02				0			3.56															
REF									1.97															
Total		-0.02	0	0.13	0.49	0	-3.29	3.56	0	-0.27	-0.19													

Difference checks (in PJ)																Total	
	OILGSL	OILHFO	OILHSD	OILKER	OILLOO	OILPLG	OILNAP	BIDCRF	BIDCRP	BIODNF	BIODNP	BIOVDF	BIOVDF	RMWHYD			
ELE																	
GASPIIP																	
IMP			-3.45	-8.61		-2.1											
MIN					0			0	0	0	0	0	0	0.13	0		
REF	1.23	4.58	6.63	0.01	0.86	0.17	2.58										
Total	1.23	-4.87	-1.92	0.01	0.86	-1.92	2.58	0	0	0	0	0	0	0.13	0	-3.49	0.1%

- **Energy consumption in the electricity sector.** The calibration difference is currently <0.5%. A much more detailed calibration check can be found in the B-Y ELC template, worksheet *Calibration*. In this sheet, expected fuel consumption and generation by plant is assessed and checked. This uses a VBE update table, namely *CL_Power Plants Fuel Use and Generation*.
- **Electricity consumption by timeslice.** The purpose of this check is to assess whether the model is reproducing the load profile observed for 2006/07, as reported by the electricity distribution companies. Below is the current comparison, with the time series labeled “(R)” actual reported data by distribution companies. The match is reasonable, with the exception of the summer night discrepancy, which is currently being resolved.

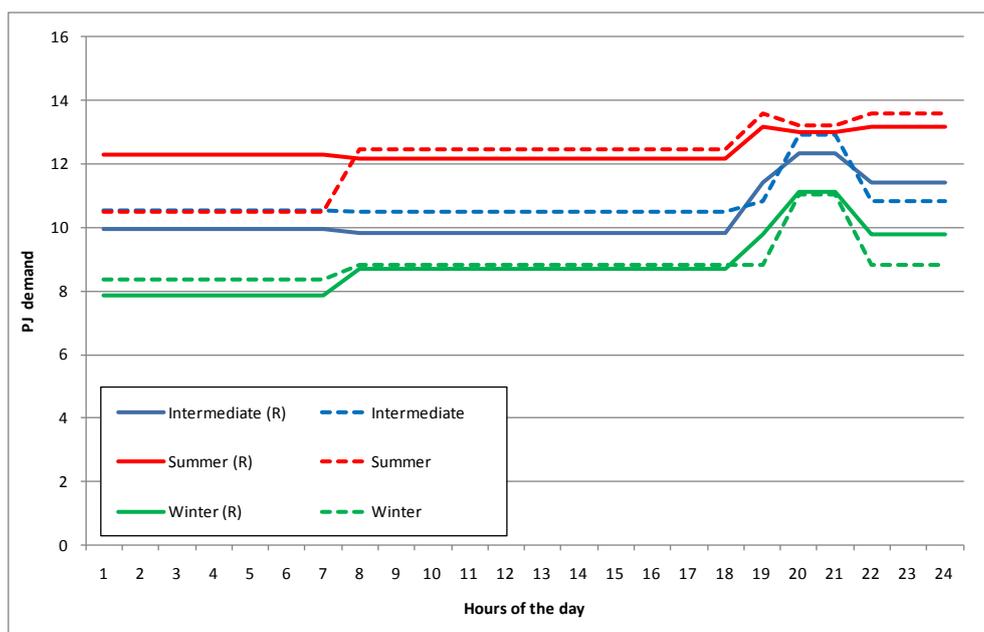


Figure 46: Demand Allocation Template (Dem_Alloc+Series)

B. Guide to Establishing the Reference Scenario(s)

As discussed in the Pak-IEM Final Report: Volume I – Model Design, the Reference Scenario is critical to the credible use of any model, since it serves as the point of comparison for how events, policies, and options impact the evolution of the energy system. The primary issue for the development of such a Reference Scenario is consensus building among the key energy system experts and stakeholders familiar with the core components of the model. There are then a number of control mechanisms that are used to guide the evolution of the Reference Scenario.

The typical set of mechanisms include the:

- Forecast for the future demand for energy services
- Price of energy resource - domestic and imported
- Rate at which fuel switching is permitted at the sector and sub-sector levels
- Rate at which new advanced technologies, typically more expensive but also more efficient, may enter the energy system or level of the "hurdle rate"⁶ impeding their uptake

In addition, circumstances particular to Pakistan require that consideration also needs to be given to the:

- Required minimum operation of existing power plants
- Known new builds (actually under construction or far along in design)
- Timing of the electricity load, overall and by sector/demand

⁶ A "hurdle rate" is a technology (or sector) specific discount rate that reflects behavior, lack of knowledge, unavailability of capital, and other impediments to the purchase of advanced technologies.

- Level and timing for removal of energy taxes/subsidies (by sector)
- Rate at which the need for load-shedding can be overcome

Each of these parameters will need to be set to agreed upon consensus levels to establish the Reference Scenario. While it is always desirable to gain enough consensus for a single Reference Scenario, this may not always be possible. Therefore, several versions of the Reference Scenario may be required to capture different views of the future that may exist among the key stakeholders. Furthermore, for certain studies there may be reason to establish an alternate reference scenario against which to compare the implications of other policy or development scenarios.

Many of these topics were discussed in the Pak-IEM Final Report: Volume I – Model Design. Here, the operational requirements to make adjustments to the assumptions guiding the Reference Scenario are discussed.

1. Demand Projection

As discussed in the Pak-IEM Final Report: Volume I – Model Design, Demand Projection section, base year demands for useful energy services are derived as part of the calibration process, and serve to seed the projection of future demands for energy services based upon the various drivers and the way they are associated with the individual demands. The relationships employed for Pak-IEM are described in full in the MDR.

The Pak-IEM templates *Dem_Alloc+Series* and *ScenDem_DEM_PIEM<scen>* constitute the vehicles for defining a consistent set of demand projections reflecting a particular view of the evolution of the Pakistan economy and demographics and how they will impact the need for energy services over the next 20 to 30 years. Demand projections as managed by VEDA-FE and passed to TIMES are a function of three things:

- Initial year B-Y demand
- A number of Drivers (growth rates) covering the planning horizon that are applied to the initial B-Y demand
- A Series multiplier running out over the planning horizon that is applied

The *Dem_Alloc+Series* template DriverAllocation sheet, shown in Figure 47 informs VEDA-FE of which individual named Drivers are associated with each sub-sector demand. The Series tab in that template defines the value for the Series called Constant, which is 1 for all periods.

	A	B	C	D	E	F	G
1							
2			~DRVR_Allocation				
3		Region	Demand	Driver		Calibration	Sensitivity
4	Agriculture	PAK	AWP	Agriculture Water pumping		Constant	Constant
5	Agriculture	PAK	ATH	Agriculture Tractors - Haulage		Constant	Constant
6	Agriculture	PAK	ATF	Agriculture Tractors - Farm Op.		Constant	Constant
7	Agriculture	PAK	AOE	Agriculture Other Use		Constant	Constant
8	Commercial	PAK	CH	Commercial Space Heating		Constant	Constant
9	Commercial	PAK	CW	Commercial Water Heating		Constant	Constant
10	Commercial	PAK	CC	Commercial Space Cooling (Fans and AC)		Constant	Constant
11	Commercial	PAK	CK	Commercial Cooking		Constant	Constant
12	Commercial	PAK	CL	Commercial Lighting		Constant	Constant
13	Commercial	PAK	CR	Commercial Refrigeration		Constant	Constant
14	Commercial	PAK	CM	Commercial Electrical Appliances		Constant	Constant
15	Commercial	PAK	CO	Commercial Other		Constant	Constant
16	Residential	PAK	RUH	Residential Urban Space Heating		Constant	Constant
17	Residential	PAK	RUW	Residential Urban Water Heating		Constant	Constant
18	Residential	PAK	RUF	Residential Urban Space Cooling (Fans)		Constant	Constant
19	Residential	PAK	RUA	Residential Urban Space Cooling (AC & Coolers)		Constant	Constant
20	Residential	PAK	RUL	Residential Urban Lighting		Constant	Constant
21	Residential	PAK	RUK	Residential Urban Cooking		Constant	Constant
22	Residential	PAK	RUR	Residential Urban Refrigeration		Constant	Constant
23	Residential	PAK	RUM	Residential Urban Miscellaneous Electric		Constant	Constant
24	Residential	PAK	RUO	Residential Urban Other		Constant	Constant
25	Residential	PAK	RRH	Residential Rural Space Heating		Constant	Constant
26	Residential	PAK	RRW	Residential Rural Water Heating		Constant	Constant
27	Residential	PAK	RRF	Residential Rural Space Cooling (Fans)		Constant	Constant
28	Residential	PAK	RRA	Residential Rural Space Cooling (AC & Coolers)		Constant	Constant
29	Residential	PAK	RRL	Residential Rural Lighting		Constant	Constant
30	Residential	PAK	RRK	Residential Rural Cooking		Constant	Constant

Figure 47: Demand Allocation Template (Dem_Alloc+Series)

The Driver values for each Scenario are derived according to the relationships established in the *ScenDem_DEM_PIEM<scen>* templates. The three templates (Ref, Med and Low) are identical except for the specification of the demand scenario, which is entered in cell A2 of the GDP sheet. When modifications are made to the demand projections, the Ref template (*ScenDem_DEM_PIEMRef*) should be treated as the master workbook and all changes made there. Once the changes are complete and the revised Ref workbook saved, new Med and Low templates can be created by changing cell A2 of the GDP sheet and doing a Save to the file names for Med and Low. This procedure will avoid having to make identical changes in three workbooks and prevent mismatches between the three demand scenario files. See Figure 48.

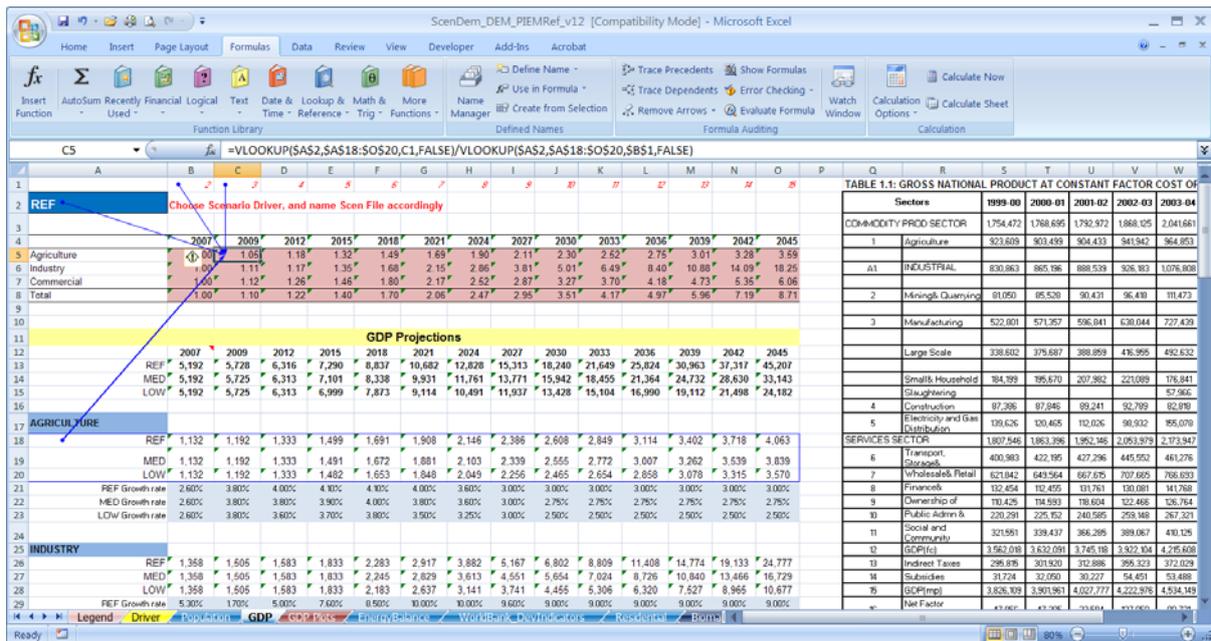


Figure 48: Selection of the Demand Scenario in the Demand Template

In each of the demand templates there is a projection of the core drivers (e.g., GDP, population, etc.) tied to their associated source data, and various sector-based calculations are then performed to establish the actual Drivers used by VEDA-FE to generate the demand projections, which are contained in the Driver sheet of each demand template, as shown in Figure 49. The development of the demand projection workbook is covered in detail in the Pak-IEM Final Report: Volume I – Model Design and the user should refer there before making changes to the demand templates.

		D	E	F	G	H	I	J	K	L	M	N	O	P	Q
		2007	2009	2012	2015	2018	2021	2024	2027	2030	2033	2036	2039	2042	2045
6	Driver														
7	Residential Urban Space Heating	1.00	1.15	1.40	1.67	1.95	2.28	2.63	3.02	3.47	3.97	4.49	5.06	5.70	6.41
8	Residential Urban Water Heating	1.00	1.15	1.40	1.67	1.95	2.28	2.63	3.02	3.47	3.97	4.49	5.06	5.70	6.41
9	Residential Urban Space Cooling (Fans and Co	1.00	1.17	1.44	1.71	2.00	2.34	2.69	3.10	3.55	4.07	4.60	5.18	5.84	6.57
10	Residential Urban Space Cooling (AC)	1.00	1.20	1.56	2.02	2.59	3.31	4.22	5.34	6.74	8.49	10.35	12.59	15.28	18.50
11	Residential Urban Lighting	1.00	1.17	1.44	1.71	2.00	2.34	2.69	3.10	3.55	4.07	4.60	5.18	5.84	6.57
12	Residential Urban Cooking	1.00	1.15	1.40	1.67	1.95	2.28	2.63	3.02	3.47	3.97	4.49	5.06	5.70	6.41
13	Residential Urban Refrigeration	1.00	1.16	1.45	1.81	2.25	2.79	3.45	4.27	5.28	6.52	7.81	9.34	11.17	13.34
14	Residential Urban Miscellaneous Electric	1.00	1.17	1.44	1.71	2.00	2.34	2.69	3.10	3.55	4.07	4.60	5.18	5.84	6.57
15	Residential Urban Other	1.00	1.15	1.40	1.67	1.95	2.28	2.63	3.02	3.47	3.97	4.49	5.06	5.70	6.41
16	Residential Rural Space Heating	1.00	1.07	1.15	1.24	1.33	1.42	1.54	1.65	1.77	1.89	2.04	2.20	2.36	2.54
17	Residential Rural Water Heating	1.00	1.07	1.15	1.24	1.33	1.42	1.54	1.65	1.77	1.89	2.04	2.20	2.36	2.54
18	Residential Rural Space Cooling (Fans and Co	1.00	1.12	1.23	1.34	1.46	1.58	1.72	1.86	1.99	2.12	2.28	2.45	2.63	2.82
19	Residential Rural Space Cooling (AC)	1.00	1.15	1.42	1.73	2.10	2.54	3.05	3.65	4.35	5.17	6.13	7.24	8.54	10.05
20	Residential Rural Lighting	1.00	1.07	1.15	1.24	1.33	1.42	1.54	1.65	1.77	1.89	2.04	2.20	2.36	2.54
21	Residential Rural Cooking	1.00	1.07	1.15	1.24	1.33	1.42	1.54	1.65	1.77	1.89	2.04	2.20	2.36	2.54
22	Residential Rural Refrigeration	1.00	1.12	1.32	1.55	1.82	2.14	2.50	2.92	3.41	3.97	4.62	5.38	6.24	7.25
23	Residential Rural Miscellaneous Electric	1.00	1.12	1.23	1.34	1.46	1.58	1.72	1.86	1.99	2.12	2.28	2.45	2.63	2.82
24	Residential Rural Other	1.00	1.07	1.15	1.24	1.33	1.42	1.54	1.65	1.77	1.89	2.04	2.20	2.36	2.54
25	Agriculture Water pumping	1.00	1.04	1.15	1.27	1.41	1.57	1.74	1.91	2.05	2.21	2.38	2.56	2.76	2.97
26	Agriculture Tractors - Haulage	1.00	1.04	1.13	1.25	1.38	1.52	1.67	1.81	1.94	2.07	2.21	2.36	2.52	2.70
27	Agriculture Tractors - Farm Op.	1.00	1.03	1.12	1.22	1.34	1.46	1.60	1.72	1.83	1.94	2.06	2.18	2.31	2.45
28	Agriculture Other Use	1.00	1.04	1.15	1.27	1.41	1.57	1.74	1.91	2.05	2.21	2.38	2.56	2.76	2.97
29	Transport Buses	1.00	1.07	1.13	1.25	1.44	1.67	1.92	2.19	2.50	2.88	3.33	3.88	4.54	5.34
30	Transport Cars	1.00	1.10	1.22	1.41	1.71	2.06	2.48	2.96	3.53	4.20	5.01	6.01	7.25	8.79
31	Transport Trucks	1.00	1.08	1.16	1.30	1.53	1.79	2.09	2.42	2.80	3.18	3.63	4.16	4.80	5.56
32	Transport Delivery Vans	1.00	1.08	1.16	1.30	1.53	1.79	2.09	2.42	2.80	3.18	3.63	4.16	4.80	5.56
33	Transport Two-wheelers	1.00	1.09	1.22	1.41	1.71	2.06	2.48	2.96	3.53	4.20	5.01	6.01	7.25	8.79
34	Transport Three-wheelers	1.00	1.09	1.19	1.35	1.61	1.92	2.28	2.68	3.15	3.63	4.20	4.89	5.73	6.74
35	Transport Taxis	1.00	1.09	1.19	1.35	1.61	1.92	2.28	2.68	3.15	3.63	4.20	4.89	5.73	6.74
36	Transport Minivans	1.00	1.07	1.13	1.25	1.44	1.67	1.92	2.19	2.50	2.88	3.33	3.88	4.54	5.34
37	Transport Rail Passenger	1.00	1.07	1.13	1.25	1.44	1.67	1.92	2.19	2.57	3.01	3.54	4.18	4.97	5.94
38	Transport Rail Freight	1.00	1.10	1.22	1.41	1.71	2.06	2.48	2.96	3.53	4.07	4.72	5.49	6.43	7.58
39	Transport Aviation	1.00	1.10	1.22	1.42	1.73	2.10	2.54	3.05	3.66	4.31	5.10	6.06	7.24	8.70
40	Transport Shipping	1.00	1.09	1.19	1.35	1.61	1.92	2.28	2.68	3.15	3.63	4.20	4.89	5.73	6.74
41	Commercial Space Heating	1.00	1.10	1.20	1.35	1.61	1.88	2.12	2.35	2.59	2.85	3.12	3.43	3.77	4.13
42	Commercial Water Heating	1.00	1.10	1.21	1.38	1.66	1.95	2.21	2.47	2.75	3.04	3.36	3.72	4.11	4.55

Figure 49: Demand Drivers in the Demand Template

2. The Reference Scenario Control Files

In order to properly guide the Reference Scenario, which includes specifying limits on the rates that old power plants can be abandoned or new ones built, new demand devices deployed and fuel switching take place, a series of REF-<purpose> files are employed, as discussed in the section. In most cases these files employ user-defined constraints are used to impose these views on the evolution of the energy system as needed.

2.1. Employing TIMES User Constraints

TIMES and VEDA have a power facility that permits the analyst to construct custom user-defined constraints. These constraints are used for a gauntlet of reasons when constraints are needed that are not inherently part of TIMES, and (most often) when a constraint applies to more than a single process. A good example are the build rate constraints discussed in Section IV.2.2.1 and shown in Figure 50 where an upper limit is imposed on a suite of power plants according to the fuel type, and Section IV.2.4 where fuel share constraints in the Commercial sector are discussed.

The basic principle behind standard user constraints are described here, but the user is referred to the <http://www.kanors.com/VedaSupport/index.htm> for a fuller description of how to construct user constraints for VEDA and the TIMES manual for an explanation of the full breadth of capabilities embodied in the user constraint facility (e.g., use as alternate objective functions, applying input data).

A user constraint is formed by identifying the specific variables (e.g., activity (ACT), capacity (CAP), new capacity investments (NCAP)) that are to be associated with one another to form

the constraint; identifying which elements are to appear on the left-hand side of the constraints and those on the right (latter with a minus sign).

Again, the user is referred to the numerous examples in the rest of this section for explicit constraint constructs, in particular the discussion in Section IV.2.4 related to Figure 63 where the various VEDA column headers for defining the qualifier rules are laid out.

2.2. Refining the Supply and Power Sectors

There are a number of critical decisions that need to be made relative to the supply and power sector as it relates to the Reference Scenario. As discussed in this section, the *Scen_REF-ELC_v##* workbook contains sheets to handle a number of these upstream issues.

2.2.1. Limits on New Build Rates

The rate at which new power generation technologies can be built (New Build Rates) are managed on sheet *BuildRates* as shown in Figure 50. They are currently implemented according to power plant fuel types, although any grouping of like plants can be set up on the sheet. For the Model Year [Col-F] listed, the corresponding length of each period needs to be provided in Col-M so that the annual limit on additions of new capacity can be converted to period limits that need to be imposed in the model.

Control of New Build Rates by Plant Type										User control values		
- Adjust the annual limit for each group, by year (Col-L) - Adjust the number of years per period and Model Year entries when the MileStoneRun years change (Col-MF) *UC_Sets: R,E: AllRegions Max new capacity additions: *UC_1: UC_PHSRT'S'UP Year UC_NCAP_PAK 0										Type	Build rate / year	Period length
11	Annual build constraint on centralised hydro plant	AU_ELC_NCAP-HYD	PWRHYD	"N	2010	1	1.00	1	1	Hydro	1.00	1
12			PWRHYD	"N	2011	1	1.00	1	1		1.00	1
13			PWRHYD	"N	2012	1	1.00	1	1		1.00	1
14			PWRHYD	"N	2013	1	1.00	1	1		1.00	1
15			PWRHYD	"N	2014	1	1.00	1	1		1.00	1
16			PWRHYD	"N	2015	1	1.00	1	1		1.00	1
17			PWRHYD	"N	2016	1	2.00	1	1		1.00	2
18			PWRHYD	"N	2020	1	7.50	1	1		1.50	5
19			PWRHYD	"N	2025	1	7.50	1	1		1.50	5
20			PWRHYD	"N	2030	1	7.50	1	1		1.50	5
21			PWRHYD	"N	2035	1	7.50	1	1		1.50	5
22			PWRHYD	"N	2040	1	7.50	1	1		1.50	5
24	Annual build constraint on solar generation plant	AU_ELC_NCAP-SOL	PWRSOL	"N	2010	1	0	1	1	Solar	0	1
25			PWRSOL	"N	2011	1	0.001	1	1		0.001	1
26			PWRSOL	"N	2012	1	0.001	1	1		0.001	1
27			PWRSOL	"N	2013	1	0.001	1	1		0.001	1
28			PWRSOL	"N	2014	1	0.001	1	1		0.001	1
29			PWRSOL	"N	2015	1	0.001	1	1		0.001	1
30			PWRSOL	"N	2016	1	0.002	1	1		0.001	2

Figure 50: BuildRates Sheet in SCEN_REF-ELC template

The analyst needs to keep these build rate limits in mind, particularly when conducting sensitivity analyses that may require higher build rates for certain plant types (e.g., a renewable electricity target scenario may need to allow more wind and solar to be deployed). The way to tell if a build rate bound is reached and impacting the solution is to examine VBE Marginals-UserConstraint table. As can be seen in Figure 51, in the current Reference scenario a number of these bounds are reached – where the system cost could be reduced by the amount shown if another GW of new capacity was permitted in any sector with a negative marginal.

Marginals - UserConstraints								
Original Units:		Active Unit	Data values filter:					
Attribute	Region	TimeSlice	Period					
~Scenario~	UserConstraint	2010	2014	2017	2020	2023	2026	2030
B-Ref_0621-02g	AU_ELC_NCAP-COA	~	~	~	-71.64	~	~	-140.23
	AU_ELC_NCAP-HYD	~	~	-810.49	-592.89	-553.53	-338.79	0.00
	AU_ELC_NCAP-NUC	~	~	-8.15	-64.58	-179.13	-105.83	~
	AU_ELC_NCAP-SOL	~	~	~	~	~	-1.63	-30.86
	AU_ELC_NCAP-WIN	~	-237.18	-273.68	-118.92	-76.66	-74.87	-77.13

Figure 51: Build Rate Marginals – UserConstraints Table

2.2.2. Forced operation of existing plants

It is often the case that old inefficient power plants with high operating and fuel costs are not selected to operate by the model. Instead, the model finds it is more cost-effective to replace these plants with modern more efficient power plants. However, except perhaps under extreme circumstances, this is not an acceptable option. As a result, a mechanism has been set up on the *ForcedOperation* sheet that forces a minimum level of operation from any power plant. Figure 52 shows that a User Constraint⁷ (UC) is employed for each technology to set a lower activity limit, which is coupled to the annual operation level arising from the base year (2007) calibration of the model. That value is automatically imported into the FILL_FO sheet and linked to Col-H of the ForcedOperation sheet. This value becomes the “seed” for the minimum level of operation over the remaining lifetime of the plant. The analyst can adjust this minimum by providing a factor other than 1 in Col-L.

Establish the Minimum Plant Operation Level										
- Adjust the relaxation factor to lower the AF relative to the 1st period value [Col-L]										
Constraint root / description		UC_ExELEUtil		Lower bound on utilization of						
~UC_Sets: R_E: AllRegions										
~UC_Sets: T_E:				~UC_T:2008*LO						
UC_Desc	UC_N	Attrib_Cond	Pset_Set	Pset_PN	UC_ACT	UC_GAP	UC_RHSRTS	UC_RHSRTS-0	Relaxation Factor	
\\: Description of Constraint	Name of the equation	Process set	qualifier	Plant (Model) Name	Capacity to	Availability in BY adj	RHS Interpolate Rule			
Lower bound on utilization of ETSTMNGA-GUDIV-E	UC_ExELEUtil ETSTMNGA-GUDIV-E	Stock	ELE	ETSTMNGA-GUDIV-E	0.03171	-85%	0	5	1	
Lower bound on utilization of ETSTMNGA-GUDIII-E	UC_ExELEUtil ETSTMNGA-GUDIII-E	Stock	ELE	ETSTMNGA-GUDIII-E	0.03171	-30%	0	5	1	
Lower bound on utilization of ETCCNGA-GUDII-E	UC_ExELEUtil ETCCNGA-GUDII-E	Stock	ELE	ETCCNGA-GUDII-E	0.03171	-91%	0	5	1	
Lower bound on utilization of ETCCNGA-GUDI-E	UC_ExELEUtil ETCCNGA-GUDI-E	Stock	ELE	ETCCNGA-GUDI-E	0.03171	-99%	0	5	1	
Lower bound on utilization of ETSTMNGA-M-GARI-E	UC_ExELEUtil ETSTMNGA-M-GARI-E	Stock	ELE	ETSTMNGA-M-GARI-E	0.03171	-73%	0	5	1	
Lower bound on utilization of ETSTMNGA-M-GARII-E	UC_ExELEUtil ETSTMNGA-M-GARII-E	Stock	ELE	ETSTMNGA-M-GARII-E	0.03171	-83%	0	5	1	
Lower bound on utilization of ETSTMNGA-M-GARIII-E	UC_ExELEUtil ETSTMNGA-M-GARIII-E	Stock	ELE	ETSTMNGA-M-GARIII-E	0.03171	-61%	0	5	1	
Lower bound on utilization of ETSTMNGA-JAMII-E	UC_ExELEUtil ETSTMNGA-JAMII-E	Stock	ELE	ETSTMNGA-JAMII-E	0.03171	-56%	0	5	1	
Lower bound on utilization of ETSTMNGA-JAMIII-E	UC_ExELEUtil ETSTMNGA-JAMIII-E	Stock	ELE	ETSTMNGA-JAMIII-E	0.03171	-83%	0	5	1	
Lower bound on utilization of ETGTNGA-FABVI-E	UC_ExELEUtil ETGTNGA-FABVI-E	Stock	ELE	ETGTNGA-FABVI-E	0.03171	-28%	0	5	1	
Lower bound on utilization of ETCCNGA-FABIV-E	UC_ExELEUtil ETCCNGA-FABIV-E	Stock	ELE	ETCCNGA-FABIV-E	0.03171	-38%	0	5	1	
Lower bound on utilization of ETSTMNGA-MULVII-E	UC_ExELEUtil ETSTMNGA-MULVII-E	Stock	ELE	ETSTMNGA-MULVII-E	0.03171	-67%	0	5	1	

Figure 52: ForcedOperation Sheet in SCEN_REF-ELC template

The Fill-FO sheet used a VFE function called a Fill Table, shown in Figure 53, which grabs model input from a particular scenario and enters them in the table so that they can be used in scenario templates, in this case AFA.

7 Note that a User Constraint (UC) is employed to set the lower activity limit since the TIMES AFA parameter does not accept LO, only FX and UP.

~TFM_FILL					
Operation_Sum_Avg_	Scenario Name	Attribute	Year	PAK	Pset_PN
AVERAGE VALUE (RETURNED)			Model Year		Plant (Model) Name
A	BASE	AFA	2007		0.85 ETSTMNGA-GUDIV-E
A	BASE	AFA	2007		0.30 ETSTMNGA-GUDIII-E
A	BASE	AFA	2007		0.91 ETCCNGA-GUDII-E
A	BASE	AFA	2007		0.99 ETCCNGA-GUDI-E
A	BASE	AFA	2007		0.73 ETSTMNGA-M-GARI-E
A	BASE	AFA	2007		0.83 ETSTMNGA-M-GARII-E
A	BASE	AFA	2007		0.61 ETSTMNGA-M-GARIII-E
A	BASE	AFA	2007		0.56 ETSTMNGA-JAMI-E
A	BASE	AFA	2007		0.83 ETSTMNGA-JAMII-E
A	BASE	AFA	2007		0.28 ETGTNGA-FABVI-E
A	BASE	AFA	2007		0.38 ETCCNGA-FABIV-E
A	BASE	AFA	2007		0.67 ETSTMNGA-MULVII-E
A	BASE	AFA	2007		0.24 ETGTNGA-KOTIV-E
A	BASE	AFA	2007		0.71 ETCCNGA-KOTIII-E
A	BASE	AFA	2007		0.52 ETSTMCOA-LAK-E
A	BASE	AFA	2007		0.63 ETSTMNGA-FABV-E
A	BASE	AFA	2007		0.10 ETGTNGA-SHA-E
A	BASE	AFA	2007		0.22 ETGTNGA-QUE-E
A	BASE	AFA	2007		0.54 ETSTMNGA-BinQa-E
A	BASE	AFA	2007		0.38 ETSTMNGA-Korangi-E
A	BASE	AFA	2007		0.23 ETGTNGA-SITE-E
A	BASE	AFA	2007		0.42 ETGTNGA-Korangi-E
A	BASE	AFA	2007		0.70 ETCCNGA-Kot-E
A	BASE	AFA	2007		0.69 ETSTMHFO-Hub-E
A	BASE	AFA	2007		0.74 ETENGHFO-Kho-E
A	BASE	AFA	2007		0.44 ETSTMHFO-AESL-E
A	BASE	AFA	2007		0.63 ETSTMHFO-AESP-E
A	BASE	AFA	2007		0.52 ETENGHFO-Sou-E

Figure 53: VFE Fill Table for Power Plant Availability

Again, the analyst should check the Marginals – User Constraint table in VBE to identify those plants that the model would prefer to operate less than is forced here, and as can be seen in Figure 54 many of these plants are not economical relative to other options available to the model because their operation increases the system by the amount shown (in \$M per PJ).

UserConstraint	2010	2014	2017	2020	2023	2026	2030
UC_ExELEUtil_ETCCHFO-Sab-E	1,016.87	490.93	192.42	695.24	897.73	841.65	542.47
UC_ExELEUtil_ETCCNGA-FABIV-E	619.01	515.80	~	~	~	~	~
UC_ExELEUtil_ETCCNGA-Fau-E	528.75	294.88	20.43	597.12	982.58	1,436.55	1,676.85
UC_ExELEUtil_ETCCNGA-GUDI-E	603.80	486.55	257.23	887.66	~	~	~
UC_ExELEUtil_ETCCNGA-GUDI-E	730.70	740.79	560.76	~	~	~	~
UC_ExELEUtil_ETCCNGA-KOTIII-E	641.43	561.14	~	~	~	~	~
UC_ExELEUtil_ETCCNGA-Kot-E	481.29	95.37	~	293.58	595.62	890.80	~
UC_ExELEUtil_ETCCNGA-Lib-E	464.75	194.15	~	465.25	831.90	1,259.60	1,461.98
UC_ExELEUtil_ETCCNGA-Rus-E	462.83	192.23	~	463.32	829.97	1,257.68	1,460.05
UC_ExELEUtil_ETENGHFO-Kho-E	958.99	412.74	98.66	586.86	~	~	~
UC_ExELEUtil_ETENGHFO-Sou-E	987.82	445.13	133.80	624.56	~	~	~
UC_ExELEUtil_ETENGHFO-UCH-E	881.19	324.00	1.54	481.86	672.79	~	~
UC_ExELEUtil_ETENGNGA-Hab-E	484.67	228.12	~	511.14	~	~	~
UC_ExELEUtil_ETGTNGA-FABVI-E	919.27	~	~	~	~	~	~
UC_ExELEUtil_ETGTNGA-KOTIV-E	1,315.09	~	~	~	~	~	~
UC_ExELEUtil_ETGTNGA-Korangi-E	974.22	1,216.65	1,126.53	1,922.72	2,552.12	3,346.76	4,078.84
UC_ExELEUtil_ETGTNGA-QUE-E	1,012.66	~	~	~	~	~	~
UC_ExELEUtil_ETGTNGA-SHA-E	1,820.39	~	~	~	~	~	~
UC_ExELEUtil_ETGTNGA-SITE-E	974.22	1,216.65	1,126.53	1,922.72	2,552.12	3,346.76	4,078.84
UC_ExELEUtil_ETNUC-CHASHN-E	25.15	~	~	~	~	~	~
UC_ExELEUtil_ETNUC-KANUPP-E	25.15	~	~	~	~	~	~
UC_ExELEUtil_ETSTMCOA-LAK-E	738.54	552.48	1,442.21	602.68	877.65	~	~
UC_ExELEUtil_ETSTMHFO-AESL-E	1,027.72	504.20	207.56	712.13	915.52	858.05	~
UC_ExELEUtil_ETSTMHFO-AESP-E	1,027.72	504.20	207.56	712.13	915.52	858.05	~
UC_ExELEUtil_ETSTMHFO-Hub-E	1,027.95	504.43	207.79	712.36	915.75	858.28	~
UC_ExELEUtil_ETSTMHFO-Jap-E	967.96	425.28	113.94	604.71	801.01	754.47	454.99
UC_ExELEUtil_ETSTMNGA-BinQa-E	652.83	412.96	153.52	739.28	1,115.16	1,506.15	1,693.88

Figure 54: Forced Operation Marginals – UserConstraints Table

2.2.3. Discrete Lumpy Investments for Major Projects

In a linear programming model such as MARKAL/TIMES, the optimal solution is continuous and investments in technology can have any value. Generally this is fine because technologies are grouped in classes and the incremental investments selected by the model are much larger than the unit size of the technology. However, for some types of power plants and for large infrastructure projects (such as pipelines, LNG terminals, transmission lines), the technology corresponds to a specific project, and the project cannot be built at less than a minimum size. In these cases, the technology needs to be discrete in nature. That is built to a specific size, or increments of a specific size, or not at all, and the model run needs to incorporate a mixed integer problem (MIP) solver.⁸

To define an individual new technology option as a discrete (or lumpy) investment changes to two templates are needed. First, in the NewTech SubRES template, the technology set declaration must include "DSCINV" as can be seen in Figure 55 for ERDAMHYD-Diameter-N. Second, in the same template on the ELC_LumpyInv sheet, the parameter NCAP_DISC needs to be provided as shown in Figure 56. Two types of entries are required. The first specifies the size of the discrete investment, and there can be several of these entries if multiple increments are to be allowed. The second entry is the extrapolation rule if the discrete investment is to be allowed to occur in other periods.

⁸ The MIP solver will increase the model run time, but this is not a problem for Pak-IEM.

New Processes - Electricity Sector								
-FI_Process								
Sets	TechName	TechDesc	Tact	Tcap	Tslvl	PrimaryCG	Vintage	
\\: Set Membership	Technology Name	Technology Description	Input Share	Lifetime	Timeslice Operational Level	Operational Commodity Group	Vintage Tracking	
ELE	ETCCNGA-N	New Gas Turbine Open Cycle - Gas or I	PJ	GW	DAYNITE		YES	
	ETCCHF0-N	New Heavy Oil Reciprocating engines w	PJ	GW	DAYNITE			
	ETSTMHFO-N	New Heavy Oil Steam turbine with Rehe	PJ	GW	DAYNITE			
	ETIGCCCOA-N	New Coal Integrated Gasification Combi	PJ	GW			YES	
	ETCCNGAHFO-N	New Gas turbine Combined Cycle - Nat	PJ	GW	DAYNITE		YES	
	ETCCRNGAHFO-N	New Gas turbine Combined Cycle with F	PJ	GW	DAYNITE			
	ETSTMNUC-N	New Nuclear Power Plant	PJ	GW			YES	
	ETSTMCOAP-N	New Coal Steam Turbine Plant (using in	PJ	GW			YES	
	ETSTMCOA-N	New Coal Supercritical Steam turbine P	PJ	GW			YES	
	ELE.DSCINV ELE	ERDAMHYD-Diamer-N	New Hydro Power Project Diamer Bas	PJ	GW	SEASON		
		ERDAMHYD-Golen-N	New Hydro Power Project Golen Gol	PJ	GW	SEASON		
		ERDAMHYD-Kurram-N	New Hydro Power Project Kurram Tan	PJ	GW	SEASON		
		ERDAMHYD-Munda-N	New Hydro Power Project Munda	PJ	GW	SEASON		
		ERDAMHYD-Kohal-N	New Hydro Power Project Kohala	PJ	GW	SEASON		
		ERDAMHYD-Keyal-N	New Hydro Power Project Keyal Khwa	PJ	GW	SEASON		
ERDAMHYD-Phanda-N		New Hydro Power Project Phandar	PJ	GW	SEASON			
ERDAMHYD-Basho-N	New Hydro Power Project Basho	PJ	GW	SEASON				
ERDAMHYD-Lawi-N	New Hydro Power Project Lawi	PJ	GW	SEASON				

Figure 55: NewTech SubRes Declaration for Discrete Investment Option

A	B	C	D	E	F	G	H	I	J	K	L
Activate Lumpy Investment for particular power plants or infrastructure projects								Author: An index # can be used to allow multiple investments of the discrete size in a period.			
~TFM_INS											
	TimeSlice	LimType	Attribute	Year	Other_Indexes	Pset_PN	PAK				
Discrete							GW/PJa or				
\\:					Increment	Plant Name	IntRule				
			NCAP_DISC	2020		1 ERDAMHYD-Diamer-N	1				
			NCAP_DISC	0		1 ERDAMHYD-Diamer-N	5				
							Author: Size (GW/PJa) of the Discrete Investment.				
							Author: permit the increment in each period going forward.				

Figure 56: Discrete Investment Scenario Parameters

The final step in making a discrete (lumpy) investment run is shown in Figure 57. At run time the Case Manager Control Panel needs to have the Discrete Investment activated under TIMES Extensions, and the OPTCR (optimization criteria) set to zero (0) to ensure a full least-cost solution.

The screenshot shows the 'Run Control Panel' dialog box with the following settings:

- Equilibrium:** Activate Macro
- OBJ Function Variant:**
 - Auto
 - Standard
 - Modified
 - Alternate
 - Linearized
 - Mid-year Discounting
 - Shift Discounting by:
- Damage:**
 - LP
 - NLP
 - NO
- Uncertainty:** Activate Stochastic
- Tradeoff:** Activate Sensitivity Analysis
GAMS Option BRATIO:
- GAMS Options:**
 - OPTCR: OPTCA:
 - ITERLIM:
 - LIMROW:
 - LIMCOL:
 - SOLPRINT
- TIMES Extensions:**
 - Endogenous Tech Learning
 - Climate Module
 - Discrete Investment
- Fix Initial Periods:**
 - Fix Years Upto:
 - From Run:
- Time-Stepped Solution:**
 - Run in steps of:
 - Overlapping Years:
- General Options:**
 - Save Solution Information
 - Write B Price for Elast Dem
 - CO2 Calibration at BOH
 - Use Slack Variables in UC
 - Do Extended QA Checks
- TS for Flow Reporting:**
 - Flow Variable
 - Commodity Level
 - Annual

Buttons: OK, Cancel

Figure 57: Invoking Discrete Investment Option at Run Time

2.2.4. Load-shedding profile

Load-shedding is an unfortunate reality in Pakistan today. As was discussed in the Pak-IEM Final Report: Volume I – Model Design, data provided by PEPCO/KESC was used to make an estimate of the unmet demand over the past three years. The LoadSheddingLevel Sheet in the SCEN_REF-ELC template contains an approach that allows the analyst to set the estimated level of current unmet demand (if updating the PEPCO/KESC data currently in the model) and to shape the profile for the elimination of load-shedding over time. This is currently set to happen by 2013 as shown in Figure 58. **{Note that the level set is above what rental power will meet.}**

To change the year at which load-shedding should be fully addressed simply move the 0 in Col-D to the desired year. Or if other than a linear drop of the load-shedding from 2009 levels is desired simply provide the desired profile.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1													
2		Establish the Load-shedding profile (from the PEPCO/KESC data) and identify the year load-shedding is to be eliminated											
3		[If other than a linear decline from the last year is desired then provide the associated levels as desired.]											
4													
5		~TFM_INS											
6		Attribute	Year	PAK		Pset_PN							
7		Model	Year	Load shedding level (PJ)		Load shedding technology							
8		ACT_BND	2007	9.1		DMYLSELC							
9		ACT_BND	2008	52.1		DMYLSELC							
10		ACT_BND	2009	75.9		DMYLSELC							
11		ACT_BND	2010			DMYLSELC							
12		ACT_BND	2011			DMYLSELC							
13		ACT_BND	2012			DMYLSELC							
14		ACT_BND	2013	0		DMYLSELC							
15		ACT_BND	2014			DMYLSELC							
16		ACT_BND	2015			DMYLSELC							

Figure 58: LoadSheddingLevel Sheet in SCEN_REF-ELC template

To complete the specification of the load-shedding, the share to be attributed to each demand sector is determined using the proportional consumption in base year for each sector. To be able to access these values in a Fill Table, “dummy” processes VT_<sect><fuel> have been created to collect the fuel consumption attribute so that the value can be grabbed by the Fill Table. As shown in Figure 59, the sector electricity consumption in the base year is collected to calculate the BY consumption shares and thereby the actual load-shedding amounts by sector. The derived shares need to be copied and pasted into the BY-SUP template in the SupplySteps sheet in cells E106-108. A similar approach is used to establish the sector fuel share constraints discussed in Demand Sector Fuel Share section below.

	A	B	C	D	E	F	G	H
1		Special (internal) VEDA attribute providing (B-Y) electric consumption levels from the sector workbooks						
2		{Used to apportion the loadshedding to the demand sectors proportionally}						
3								
4								
5		~TFM_FILL						
6		Operation_Sum_Avg_Count	Scenario Name	Attribute	Year	PAK	Pset_PN	
7		\I: SUM VALUE (RETURNED)			Model			Technology Name
8		S	BASE	VA_SectFuelCons	2007	124.22	VT_RSDEL	
9		S	BASE	VA_SectFuelCons	2007	36.44	VT_COMELC	
10		S	BASE	VA_SectFuelCons	2007	29.43	VT_AGREL	
11		S	BASE	VA_SectFuelCons	2007	78.50	VT_INDEL	
12								
13								
14								
15		Derived shares				46.2%	RSD	
16						13.6%	COM	
17						11.0%	AGR	
18						29.2%	IND	
19								
20		Load shedding values (2007, PJ)				4.23	RSD	
21						1.24	COM	
22						1.00	AGR	
23						2.67	IND	

Author:
These values should be entered into the B-Y SUP(SupplySteps) sheet in E106-109.

Figure 59: Load-Shedding Fill Table in Fill_LS sheet

2.2.5. Supply infrastructure overrides

The NewTech SubRES identifies all the known supply options that are envisioned and potentially available to Pakistan in the future. But some of these options are rather speculative, and as such it may at times be necessary to prohibit their inclusion in the Reference Scenario. Figure 60 shows that this is done in the Supply sheet of the SCEN_REF-ELC templates, where the FLO_BND (flow bound) for the Central Asia pipeline is set to 0.

No Central Asia Pipeline							
Prevent any output from the pipeline							
~TFM_UPD							
	TimeSlice	LimType	Attribute	Year	PAK	Pset_PN	
\\:	TimeSlice Level	Bound Type	*	Data Value		Process Name Qualifier	
		UP	FLO_BND	2020	0	IMPGASRAW-CentASIA-N	
			FLO_BND	0	5	IMPGASRAW-CentASIA-N	

Figure 60: Supply Sheet in SCEN_REF-ELC template – Centra Asia Pipeline

2.2.6. Provincial Coal Supply Shares

The VT_PAK_SUP BY template sets bounds for the coal resources available in each province. To prevent the model from using coal from only the lowest cost province, share constraints were developed to ensure that the proper coal use proportions were maintained initially, with some allowance for them to relax over time. Figure 61 shows how a Fill Table is used to get the base year data for coal use from each province. The calculated shares are then used to set upper bounds for each provincial coal supply resource that are relaxed over time according to the factor set by the user.

Get 1st year coal from each province							
~TFM_FILL							
Operation_Sum_Avg_Count	Scenario Name	Attribute	Year	PAK	Pset_PN		
			Model Year		Technology Name		
\\:	SUM VALUE (RETURNED)	*					
S	BASE	FLO_BND	2007	36.21	MINCOADN		
S	BASE	FLO_BND	2007	10.05	MINCOADB		
S	BASE	FLO_BND	2007	19.77	MINCOADH		
S	BASE	FLO_BND	2007	6.00	MINCOADP		
Derived shares				50.3%	MINCOADN		
				13.9%	MINCOADB		
				27.4%	MINCOADH		
				8.3%	MINCOADP		
Set the shares							
~UC_Sets: R_E: PAK							
~UC_T:UC_FLO							
UC_Desc	UC_N	Pset_PN	Cset_CN	LimType	2008	2030 ~2008	UC_RHSRTS
\\:	Description of Constraint	Name of the equation	Process Qualifier	Type of UC limit			UC_RHSRTS=0
	Share of BALOCHISTAN coal	SU_SUP_COADN	MINCOAD*,-MINCOADR,-MINCOADN	COAD	UP	-0.50	RHS Interpolate Rule
			MINCOADN	COAD		-0.70	
			MINCOADB	COAD		0	
	Share of PUNJAB coal	SU_SUP_COADB	MINCOAD*,-MINCOADR,-MINCOADB	COAD	UP	-0.14	
			MINCOADH	COAD		-0.20	
			MINCOADP	COAD		0	
	Share of SINDH coal	SU_SUP_COADH	MINCOAD*,-MINCOADR,-MINCOADH	COAD	UP	-0.27	
			MINCOADN	COAD		-0.38	
			MINCOADB	COAD		0	
			MINCOADH	COAD		0.62	
							Relaxation Factor
							1.4
							1.4
							1.4

Figure 61: Supply Sheet in SCEN_REF-ELC template – Provincial Coal Shares

2.3. Shaping the Electricity Load Timing

As discussed in the Pak-IEM Final Report: Volume I – Model Design a fundamental input to the model is the shape and timing of the electricity load, by sector and even end-use, so that based upon the demand load profile the power plant operation, and capacity requirements, are properly determined. The approach and data sources for establishing the current segmentation is discussed fully in the Pak-IEM Final Report: Volume I – Model Design, while this section of the User’s Guide only presents the mechanism for inputting the

information into the model. While it is not expected that this information will need to be changed, new information arising from a more detailed look at the Residential sector, or additional data found or secured by means of surveying will require updating the current information and adjusting the load shape calibration, as discussed here.

The Pak-IEM load profile is established in the *Scen_REF-FRs* template. This scenario file is used to estimate the TIMES parameter for the load shape (COM_FRs), which define the fraction of demand within different seasons and time of day periods for energy service demands. When aggregated, these fractions are to provide a representation of the Pakistan electricity load curve data for 2006/07.

The COM_FRs used in the model can be found in worksheet *FRs*. These are based primarily on calculations in the *Calib* worksheet, described below and shown in Figure 62.

- The overall fractions by time period from the Pakistan load curve data are provided in row 5. The purpose of the *Calib* sheet is to match these aggregate data with values in row 6. The values in row 6 are built up based on the splits provided in the data block C14:Q35. Within this data block, % values shaded yellow can be amended.
- The % values for the different energy service demands are of course weighted by electricity consumption data in the base year (in column B). ***If any base year energy totals are amended in end use sector BY templates, they need to be updated in column B.***
- The first check is to ensure that the seasonal shares of consumption reflect data for the base year. Values in cells D14:E35 need to be amended to provide a close match to the sector seasonal consumption totals, shown in C41:E46. The differences in calibration are shown in red text.
- Then values representing timing of daily demand need to be input. Yellow shaded cells in block F14:Q35 can be adjusted to reflect this. Note that these are based predominantly on expert judgment, and therefore constitute the key values that are most likely to be amended. ***However, if any of the yellow shaded cells are changed for one energy service demand, this will affect the overall calibration (difference between rows 5 and 6); hence other energy service demand shares will also need to be adjusted to ensure a close match.***

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Load curve specification		Split of year into seasons			Splits of the seasons into day parts				1.00E-08							
2		Total	I	S	W	ID	IS	IP	IN	SD	SS	SP	SN	WD	WS	WP	WN
3	Energy Split (with correction)		24.5%	48.0%	27.5%	43.6%	18.3%	9.8%	28.2%	44.8%	17.6%	8.7%	28.8%	44.9%	18.5%	10.5%	26.1%
4	Summary	PJ	fraction														
5	From Load data (w correction)	267.9	24.5%	48.0%	27.5%	43.6%	18.3%	9.8%	28.2%	44.8%	17.6%	8.7%	28.8%	44.9%	18.5%	10.5%	26.1%
6	From calibration	267.90	24.8%	48.7%	26.5%	42.0%	18.6%	10.5%	28.9%	44.4%	16.0%	9.5%	30.0%	43.9%	18.7%	9.5%	27.9%
7	Agriculture	29.43	24%	46%	30%	15%	20%	0%	65%	15%	20%	0%	65%	20%	15%	0%	65%
8	Commercial	36.44	25%	49%	26%	50.9%	21.8%	12.4%	14.9%	52.3%	18.1%	10.5%	19.0%	66%	16%	7.1%	10.7%
9	Industry	78.20	24%	43%	33%	54.5%	16.5%	6.5%	22.6%	54.7%	16.5%	6.4%	22.4%	54%	16%	7%	23%
10	Residential	123.78	25%	53%	22%	38.0%	21.4%	12.0%	28.6%	43.1%	17.2%	10.0%	29.7%	34%	39%	0.0%	26.6%
11	Transport	0.04	25%	42%	33%	60%	30.0%	10%	0%	60%	30.0%	10%	0%	60%	30%	10%	0%
12																	
13	Commercial	36.44	0.25	0.49	0.26	0.51	0.22	0.12	0.15	0.52	0.18	0.11	0.19	0.66	0.16	0.07	0.11
14	Heating		30%	0%	70%	60%	23%	12%	5%					60%	23%	12%	5%
15	Space Cooling	21.86	26%	54%	20%	65%	18%	12%	5%	65%	13%	10%	12%	95%	5%	0%	0%
16	Lighting	7.29	23%	40%	37%	5%	35%	15%	45%	5%	38%	12%	45%	30%	30%	15%	25%
17	Refrigeration	1.82	22%	50%	28%	46%	17%	8%	29%	46%	17%	8%	29%	46%	17%	8%	29%
18	Elec Appliances	3.64	25%	42%	33%	50%	23%	12%	15%	50%	18%	12%	20%	55%	23%	12%	10%
19	Other	1.82	22%	45%	33%	50%	23%	12%	15%	50%	23%	12%	15%	55%	23%	12%	10%
20	Residential	123.78	0.25	0.53	0.22	0.38	0.19	0.15	0.29	0.43	0.14	0.13	0.30	0.34	0.23	0.16	0.27
21	Heating		22%	0%	78%	40%	10%	5%	45%					42%	13%	16%	29%
22	Space Cooling	40.22	25%	70%	5%	55%	8%	12%	25%	55%	10%	10%	25%	95%	5%	0%	0%
23	Space Cooling (AC)	9.33	25%	70%	5%	55%	8%	12%	25%	55%	10%	10%	25%	95%	5%	0%	0%
24	Lighting	40.98	26%	38%	36%	5%	35%	20%	40%	5%	25%	20%	50%	10%	31%	21%	38%
25	Refrigeration	13.80	26%	50%	24%	55%	12%	8%	25%	55%	12%	8%	25%	55%	12%	8%	25%
26	Misc	19.46	24%	42%	34%	55%	15%	15%	15%	55%	15%	15%	15%	55%	17%	16%	12%
27	Industry	78.20	0.24	0.43	0.33	0.54	0.16	0.06	0.23	0.55	0.16	0.06	0.22	0.54	0.16	0.07	0.23
28	I&S (Pak Steel)	0.50	25%	42%	33%	46%	17%	8%	29%	46%	17%	8%	29%	46%	17%	8%	29%
29	I&S (Indpt)	13.29	24%	44%	32%	46%	17%	8%	29%	46%	17%	8%	29%	46%	17%	8%	29%
30	Sugar	0.13	26%	55%	19%	80%	20%	0%	0%	46%	17%	8%	29%	40%	20%	0%	0%
31	Cement	6.89	26%	41%	33%	46%	17%	8%	29%	46%	17%	8%	29%	46%	17%	8%	29%
32	Textiles	22.34	24%	41%	35%	46%	17%	8%	29%	46%	17%	8%	29%	46%	17%	8%	29%
33	Other	35.06	24%	44%	32%	65%	16%	4%	15%	65%	16%	4%	15%	65%	16%	4%	15%
34	Agriculture	29.43	0.24	0.46	0.30	0.15	0.20	0.00	0.65	0.15	0.20	0.00	0.65	0.20	0.15	0.00	0.65
35	Pumping	27.81	0.24	0.46	0.30	15%	20%	0%	65%	15%	20%	0%	65%	20%	15%	0%	65%
36	Other	1.62	0.24	0.46	0.30	15.0%	20.0%	0.0%	65.0%	15.0%	20.0%	0.0%	65.0%	20.0%	15.0%	0.0%	65.0%

Figure 62: Calib Sheet in SCEN_REF-FR

In the *Calib* sheet, rows 5 and 6 do not match exactly. To ensure full calibration, an adjustment factor is calculated in the *Final* worksheet (see row 40 of the workbook, not shown) to ensure close calibration (rows 5 and 6 in *Final* sheet should be exactly matching).

2.4. Demand Sector Fuel Shares and Device Adoption Choices

As mentioned above, two aspects of the evolution of an energy system need to be guided by expert judgment: the rate at which current fuel choice consumption patterns may change and similarly how fast end-use device choice may change over time. This is to ensure that the model retains a reasonable near term picture, with the flexibility to change but not to radically re-structure the energy system too quickly. A scenario file *Scen_REF-DMD* is used to control both aspects of change in the model across the different end-use sectors.

The technology and fuel shares are “seeded” with the base year shares, collected on the *FILL_BY-Share* worksheet. A VEDA Fill Table automatically collects data from base year templates during the next SYNC operation that imports the *Scen_REF-DMD* workbook.

A multi-level approach to applying sector/demand/fuel consumption shares has been set up in each of the worksheets labeled *[Sector]_FuelShare*, and care needs to be taken to decide which levels should be activated and to ensure that conflicts are not introduced between the levels. All sheets (except transport) have the following types of fuel shares:

- Cross-sectoral – limiting share of a fuel to a sector relative to total final energy consumption for that fuel
- Sectoral – limiting share of fuel use in a sector relative to other fuels being used in the sector
- SubSectoral – limiting share of fuel for a particular demand (e.g., commercial space heating), relative to other fuels used for that particular demand

The yellow shaded areas on the *[Sector]_FuelShare* sheets are User input areas and allow the analyst to tighten (keeping them similar to that observed in the base year) or loosen the overall share of consumption by fuel to the sector. By selecting a lower relaxation factor for a

done by examining the VBE *Marginals_UsersConstraints* table (see Figure 64), where those LO constraints that are binding will have a +value (indicating that the system is costing this much more than might otherwise be the case if less of the fuel was required) and UPs a – value if binding (indicating that the system would cost this much less if more of the fuel was permitted).

Marginals - UserConstraints		Data values filter:							
Original Units: Active Unit									
Attribute	Region	TimeSlice	Period						
Scenario	UserConstraint	2010	2014	2017	2020	2023	2026	2030	
B-Ref_0621-02g	SL_AGRAOE_ELC	~	18.85	36.35	20.89	14.85	~	~	
	SL_AGRAOE_LDO	8.94	~	~	~	~	17.36	17.08	
	SL_AGRAWP_HSD	39.23	19.47	16.87	14.52	~	~	0.25	
	SL_AGRAWP_LDO	26.00	10.71	7.11	11.91	14.64	16.59	16.44	
	SL_AGRELC	~	~	~	~	~	36.09	50.89	
	SL_AGRHSD	~	~	~	~	31.66	41.29	42.89	
	SL_BMARKET_DSL	102.70	4.56	5.20	5.80	6.11	6.41	6.77	
	SL_COMNGA	5.86	11.73	14.01	16.71	19.72	23.92	29.94	
	SL_COMOTH_AVG	11.30	13.51	0.00	0.00	0.00	~	0.00	
	SL_COMOTH_GSL	19.42	23.43	11.31	12.62	13.29	16.36	18.21	
	SL_COMOTH_HFO	11.30	13.51	0.00	~	~	0.00	~	
	SL_COMOTH_HSD	23.82	22.27	9.94	11.09	19.00	23.82	25.38	
	SL_COMOTH_LPG	15.42	18.55	5.75	0.00	0.00	~	6.89	
	SL_COMWTH_LPG	16.49	20.12	22.91	18.82	19.81	18.26	25.43	
	SL_COM_KER	10.69	1.42	0.23	~	1.91	~	~	
	SL_INDIOTP_HFO	1.40	~	~	~	~	~	~	
	SL_INDIOTP_HSD	13.92	8.76	9.94	11.09	18.22	17.37	12.92	
	SL_RSDEL	~	~	~	~	~	9.29	17.33	
	SL_RSDR_WDP	12.44	16.80	14.65	19.11	22.23	27.63	31.76	
	SL_RSD_LPG	~	7.44	7.87	1.43	~	~	~	
	SL_TRNNGA	5.85	11.72	14.00	16.70	19.71	23.91	29.97	
	SL_TRN_CARDSSL	~	~	~	~	~	~	0.00	
	SU_COM_KER	~	~	~	-1.44	~	-0.61	-7.09	
	SU_INDIOTP_NGA	-4.32	-2.37	-2.04	-1.28	~	~	~	
	SU_RSDNGA	-16.37	~	~	~	~	~	~	
	SU_RSDR_NGA	~	~	~	-3.96	-1.11	~	~	
	SU_RSDR_RRHELC	-77.33	-14.05	-1.10	-25.59	-33.87	-54.21	-66.33	
	SU_RSDR_RRHLP	-57.90	-30.98	-34.64	-42.80	-43.20	-58.35	-68.12	
	SU_RSDR_RRLCFL	~	-13.31	-26.56	-15.25	-15.97	-6.89	-9.76	
	SU_RSDU_IMPSTV	-42.74	-21.31	-17.15	-20.59	~	~	~	

Figure 64: Marginals_UsersConstraints Table – Fuel Shares

The fuel shares provided in this scenario file have been introduced on the basis of requirement, through observing near-term model behavior. However, they should provide the analyst with an understanding of how to set up any other fuel share not already included that may be deemed necessary in the future, and decide which ones to activate or not.

Technology share constraints are needed to control the rate at which advanced energy efficient devices are allowed to penetrate. This is necessary since the least-cost optimization driving the model solution works with the lifetime costs for competing technologies, and does not inherently consider factors such as the lack of knowledge by consumers of the lower life-cycle cost, unwillingness to adopt advanced technologies, or the inability of some consumers to pay the higher upfront costs usually associated with such technology. There are two possible ways to limit the advanced technology adoption rate: either use technology-specific discount rates (sometimes referred to as “hurdle rates”) which reflect the differential cost of capital in various sectors or for various purposes, or by imposing a limit on the share of advanced devices to total new devices purchased in each sector or sub-sector. Pak-IEM is using the latter approach currently, although the “hurdle rates” approach could be adopted in

the future (although determining the correct hurdle rates requires data development and some experimentation to see that the advanced high efficiency technologies penetrate at acceptable levels in the Reference scenario). The advantage of using the “hurdle rates” is that the model will overcome the extra cost when a scenario warrants it (e.g., a policy to cut imports), while when the share constraints are employed the analyst must adjust the binding constraints to permit more penetration of these devices.

The framework established to enable the technology shares to be imposed can be found in the [Sector]_TechShare worksheets (see Figure 65). For all sectors, these constraints ensure specific technologies retain a share of the energy service provided, by employing a user constraint on the technology activity. Note that a similar approach is used for defining the technology constraint parameters as was used for the fuel share constraints, where the target rate of adoption (as a negative value) is imposed on the set of all technologies less the advanced techs in the sector, and 1 minus the target rate is applied to the advanced techs.

The analyst can control the rates of technology uptake by adjusting the % uptake values, shaded yellow in Figure 65. In cell C8, a choice can be made between selecting the Reference rates (typically used in Reference case runs, with tighter controls on uptake) and the Alternative rates, used in sensitivity cases. The Alternative rates allow the analyst to relax the controls on penetration of new technologies, by defining the maximum rate permitted in the final model period (2040) – cells L8:M8. The uptake rates in the periods between 2008 (same as under the Reference case) and 2040 are linearly interpolated.

		REFERENCE					ALTERNATIVE				
		2008	2015	2020	2030	2040	2008	2015	2020	2030	2040
13	RUHNGAIMP-N New Improved Space heater, Natural Gas - Urban	3%	6%	10%	15%	20%	3%	22%	36%	63%	90%
14	RUHELIMP-N New Improved Space heater, Electricity - Urban	3%	6%	10%	15%	20%	3%	22%	36%	63%	90%
15	RUHLPGIMP-N New Improved Space heater, LPG - Urban	3%	6%	10%	15%	20%	3%	22%	36%	63%	90%
16	RUHELHPAS-N New Standard Heat pumps (Air), Electricity - Urban	1%	2%	4%	6%	10%	1%	20%	34%	62%	90%
17	RUHNGHPAS-N New Standard Heat pumps (Air), Natural Gas - Urban	1%	2%	3%	5%	7%	1%	30%	34%	62%	90%
18	RUHELCHPAS-N New Improved Heat pumps (Air), Electricity - Urban	1%	2%	3%	5%	7%	1%	22%	36%	63%	90%
19	RUWNGAIMP-N New Improved Water heater, Natural Gas - Urban	3%	6%	10%	15%	20%	3%	22%	36%	63%	90%
20	RUWLPIMP-N New Improved Water heater, LPG - Urban	3%	6%	10%	15%	20%	3%	22%	36%	63%	90%
21	RUWLPADV-N New Advanced Water heater, LPG - Urban	2%	5%	8%	11%	15%	2%	21%	36%	63%	90%
22	RUWELIMP-N New Improved Water heater, Electricity - Urban	3%	6%	10%	15%	20%	3%	22%	36%	63%	90%
23	RUWSOLSTD-N New Standard Water heater, Solar - Urban	1%	2%	4%	6%	10%	1%	20%	34%	62%	90%
24	RUELCFAN-N New Improved Fan, Electricity - Urban	16%	20%	22%	25%	28%	16%	32%	44%	67%	90%
25	Share control (LO) - Min. Level of improved fans	16%	16%	16%	16%	16%	16%	16%	16%	16%	16%
26	RUALCACH-N New Improved Air conditioner, Electricity - Urban	3%	6%	10%	15%	20%	3%	22%	36%	63%	90%
27	RUALCCLI-N New Improved Air cooler, Electricity - Urban	32%	34%	38%	38%	40%	32%	45%	54%	72%	90%
28	Share control (LO) - Min. Level of improved air coolers	32%	32%	32%	32%	32%	32%	32%	32%	32%	32%
29	Share control (UP) of coolers for urban cooling services	51%	51%	51%	51%	51%	51%	51%	51%	51%	51%
30	Share control (LO) of coolers for urban cooling services	50%	48%	48%	43%	40%	50%	48%	46%	43%	40%
31	RUELCCFLS-N New Standard CFL - Urban	45%	48%	50%	54%	58%	45%	55%	62%	70%	90%
32	Share control (LO) - Min. Level of CFLs	45%	45%	45%	45%	45%	45%	45%	45%	45%	45%
33	RULELCFTI-N New Improved FT Lighting - Urban	2%	5%	8%	11%	15%	2%	21%	35%	63%	90%
34	Share control (UP) of FT bulbs for urban lighting services	15%	16%	17%	19%	20%	15%	16%	17%	19%	20%
35	Share control (LO) of FT bulbs for urban lighting services	14%	14%	14%	14%	14%	14%	14%	14%	14%	14%
36	RUKELCIMP-N New Improved Cooker, Electricity - Urban	2%	5%	8%	11%	15%	2%	21%	35%	63%	90%

Figure 65: Advanced Technology Adoption Shares – Residential Sector

As was the case with the fuel share constraints, the analyst is encouraged to check the marginals, particular for sensitivity runs!

The industry sector has two additional worksheets relating to retrofitting energy efficiency improvements to existing industry stock.

- IND_Retrofit – This sheet controls the retrofitting of existing industry processes with higher efficiency processes, and ensures that the capacity of the retrofit technology cannot exceed that of the existing plants and that existing plant stock cannot be used if retrofitted. For each type of energy efficiency measure, three constraints are used, as shown in Figure 66.

- The first limits investment in retrofit technology to not exceed existing stock.
- The second states what the stock is, and that new tech capacity cannot exceed the remaining stock in any given year.
- The third states that the activity of stock (retrofit and old) should not exceed a certain level based on the AF factor.

Each retrofit option needs this set of three constraints established, where the B-Y stock is grabbed by VEDA using the fill table (at the bottom of the sheet).

* Retrofit of existing cement plants - dry single stage process to dry multi-stage									
UC_N	Pset_PN	LimType	UC_CAP	UC_NCAP	UC_ACT	UC_RHSRTS	UC_RHSRTS=0	UC_Desc	
~UC_T=2010									
Name of equation									
Process qualifier									
UC Limit type									
Description of constraint									
UC ICTSSRetroI	ICTPSS-E	UP	-1		1		0	15	Investment in Retrofit tech <= CAPacity(E)
	ICTPSS-N								
V:									
UC ICTSSRetroC	ICTPSS-N	UP	1				6.50	15	Capacity Retrofit <= STOCK(year-0)
V:									
UC ICTSSRetroA	ICTPSS-E	UP				1	4.55	15	ACTacity STOCK <= AF(STOCK)*(CAP(STOCK)-CAP(RRR))
	ICTPSS-N		0.7						

Figure 66: IND_Retrofit Sheet in SCEN_REF-DMD

- IND_EEUptake – This sheet controls the uptake of efficiency measures in industry based on work by Hagler Bailly for ADB (2009). A choice of three uptake rates can be chosen by the analyst using cell B6 – Reference, Hagler Bailly Assumptions or Alternative. “Reference” is more restricted than that shown in the Hagler Bailly assessment, whilst “Alternative” (as yet defined) can be used to go for more ambitious retrofitting rates.

2.5. Sector fuel price [tax/subsidies]

In Pakistan there are numerous price subsidies provided for certain fuels to different sectors at varying levels. In the *Scen_SectorPrices* scenario file a variable cost (VAROM) is added to sector fuel tracking technologies (X-processes) to reflect the levels of taxes and subsidies across different sectors in Pakistan. The typical terminology for the use of full pricing in analysis is known as a *financial* approach, as opposed to an *economic* approach, when the model is run without these additional taxes and subsidies. The difference between delivered and refinery/supplier determines markup for petroleum products/gas. All sectors pay the same markup on petroleum products, including the power sector. For gas there is some sector differential pricing, including a subsidy (-cost) to the fertilizer sector.

These sector markups for the base year can be found in the *[Sector]_SectorPrices* worksheets. They are based on three primary data sources – the Energy Year Book, the Sustainable Energy Efficiency Development Report by Hagler Bailey, and the Economic Survey. The sector-markups for fossil fuels increase in future years at the same rate as the commodity prices; these projections can be found in the *CommodityPrices* sheet. **Note that this sheet is originally sourced from the SUP base year template; any changes to the projections in the SUP BY template should be reflected in this scenario file.** For electricity, the Hagler sector based markups are retained over time.

As a default, the sector markups are all switched on. In other words, if this file is added to the model run, all of these additional variable costs will be used. However, individual fuel/sector markups can be adjusted or switched off, by changing values in Col-I to a fraction or zero. Zero turns off the markup, and a fraction would adjust the subsidy/tax current in place by the fractional amount. Note that all subsidies may be adjusted by a uniform amount

after a given year through the values in cells I6 and J6. In Figure 67, a factor of 0.8 will be applied after 2020 if the value in cell J6 were 2020 rather than 2050 as shown.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1													
2		* Fuel price sector mark-ups added as VAROM on model X-processes											
3													
4		~TFM_INS											
5		TimeSlice	Attribute	Year	PAK	Pset_PN	Pset_CO	Adjustment Factor					
6		*			Sector fuel mark-up (SM/PJ)	Process Name Qualifier	Commodity Output Qualifier	0.80	2050		Year-based factor		
7		VAROM	2007	1.99	X*	*HSD							
8		VAROM	2009	2.05	X*	*HSD			1				
9		VAROM	2015	2.79	X*	*HSD			1				
10		VAROM	2020	3.41	X*	*HSD			1				
11		VAROM	2030	3.93	X*	*HSD			1				
12		VAROM	2007	11.47	X*	*GSL							
13		VAROM	2009	11.79	X*	*GSL			1				
14		VAROM	2015	16.07	X*	*GSL			1				
15		VAROM	2020	19.64	X*	*GSL			1				
16		VAROM	2030	22.59	X*	*GSL			1				
17		VAROM	2007	0.60	X*	*LDO							
18		VAROM	2009	0.61	X*	*LDO			1				
19		VAROM	2015	0.84	X*	*LDO			1				
20		VAROM	2020	1.02	X*	*LDO			1				
21		VAROM	2030	1.18	X*	*LDO			1				
22		VAROM	2007	0.66	X*	*KER							
23		VAROM	2009	0.68	X*	*KER			1				
24		VAROM	2015	0.92	X*	*KER			1				
25		VAROM	2020	1.13	X*	*KER			1				
26		VAROM	2030	1.30	X*	*KER			1				

Author:
Adjust to reflect the removal of tax/subsidies from a point in time over all sectors, or discretely.

Figure 67: Fuel Price Sector Markup Worksheet

Note that VAROM uses the standard default inter/extrapolation rule 0, which interpolates linearly between data points, while extrapolating the first/last data point constantly backward/forward. In the above example, only removing the 2020 value will mean linear interpolation between 2009 and the end of the modeling horizon.

3. Examining Reference Scenario Runs

Section IV discusses in detail how to manage model run results and use VEDA-BE (VBE). Therefore, this section only provides a short list of key tables, grouped into the Reference Tables folder, that are very useful for examining overall model behavior and the shaping of the Reference Scenario. See Figure 68.

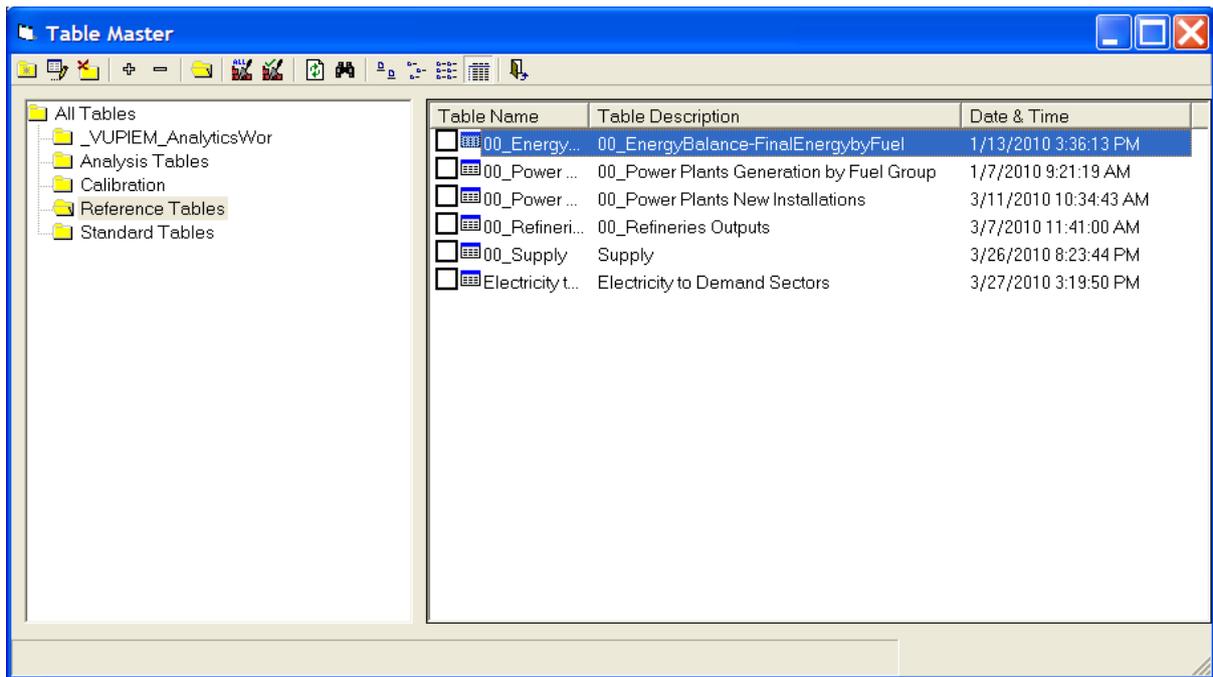


Figure 68: VBE Table Groups – Reference Tables

While these tables initially present the information in an aggregate form, moving dimensions on/off the cube area will enable the analyst to zero-in on exactly what the model is doing. For example, in Figure 69 the new capacity additions are shown by fuel group, but by bringing the Process into the view the individual plant builds can be seen as in Figure 70.

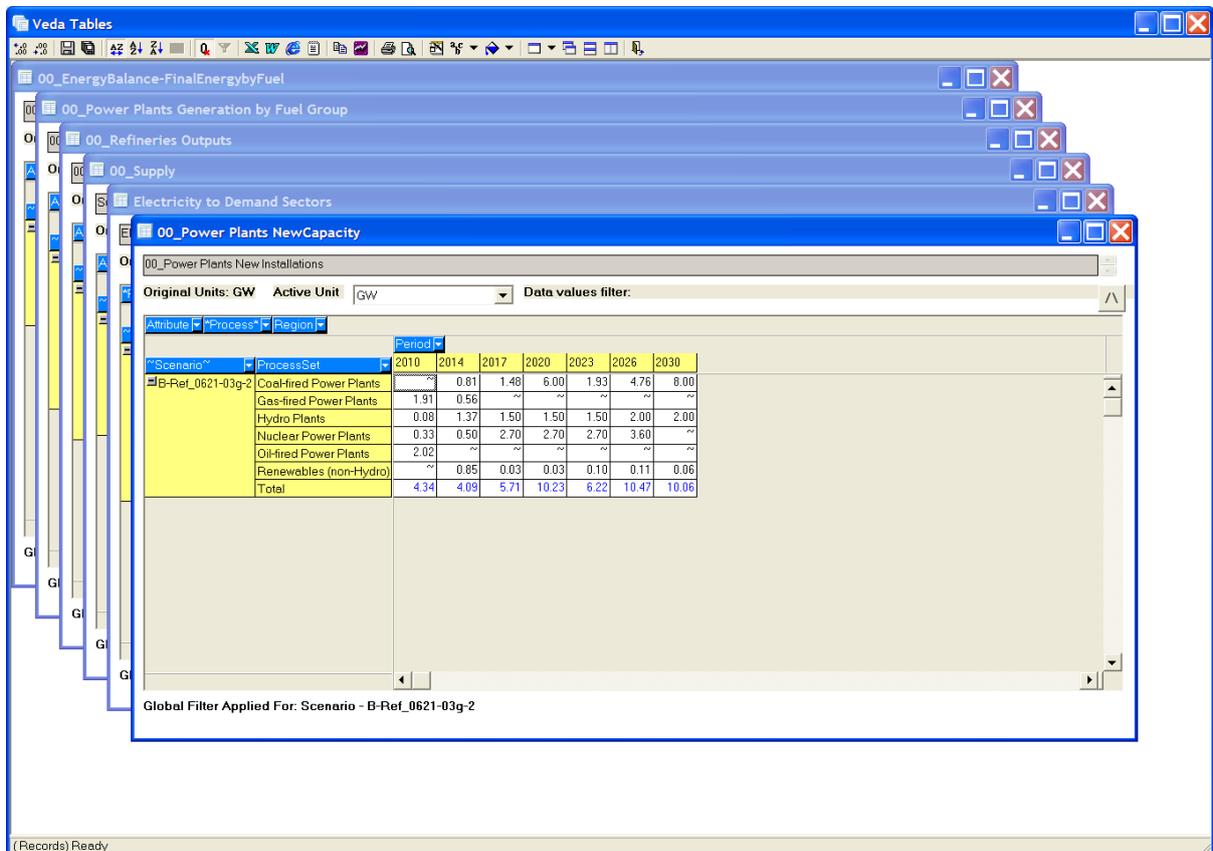


Figure 69: Reference Scenario Results – New Power Plants by Fuel Group

Scenario	ProcessSet	Process	2010	2014	2017	2020	2023	2026	2030	
B-Ref_0621-03g-2	Coal-fired Power Plants	ETGCCCOA-N	~	~	~	~	~	~	~	
		ETSTMCOA-N	~	0.81	1.48	6.00	1.93	4.51	8.00	
		Total	~	0.81	1.48	6.00	1.93	4.76	8.00	
	Gas-fired Power Plants	ETCCNGA-Bin-PN	~	0.56	~	~	~	~	~	~
		ETCCNGA-Hero-PN	0.05	~	~	~	~	~	~	~
		ETCCNGA-Kora-PN	0.22	~	~	~	~	~	~	~
		ETGTNGA-Alst-RPN	0.14	~	~	~	~	~	~	~
		ETGTNGA-Engr-PN	0.20	~	~	~	~	~	~	~
		ETGTNGA-Four-PN	0.18	~	~	~	~	~	~	~
		ETGTNGA-GE-RPN	0.15	~	~	~	~	~	~	~
		ETGTNGA-Gudd-RPN	0.11	~	~	~	~	~	~	~
		ETGTNGA-Kora-PN	0.09	~	~	~	~	~	~	~
		ETGTNGA-Orre-PN	0.21	~	~	~	~	~	~	~
		ETGTNGA-SITE-PN	0.09	~	~	~	~	~	~	~
		ETGTNGA-Sea-PN	0.21	~	~	~	~	~	~	~
		ETGTNGA-Sapp-PN	0.21	~	~	~	~	~	~	~
		ETSTMNGA-Naud-RPN	0.05	~	~	~	~	~	~	~
		Total	~	1.91	0.56	~	~	~	~	~
	Hydro Plants	ERDAMHYD-Akhor-N	~	~	~	~	0.50	0.10	2.00	~
		ERDAMHYD-Alla-PN	~	0.12	~	~	~	~	~	~
		ERDAMHYD-Bunji-PN	~	~	~	~	~	0.10	~	~
		ERDAMHYD-Diamer-N	~	~	~	1.00	1.00	1.00	~	~
		ERDAMHYD-Dudhni-N	~	~	~	~	~	0.80	~	~
		ERDAMHYD-Golen-N	~	0.11	~	~	~	~	~	~
		ERDAMHYD-Hero-PN	~	~	~	0.03	~	~	~	~
ERDAMHYD-Jinn-PN		~	0.10	~	~	~	~	~	~	
ERDAMHYD-Kurram-N		~	0.08	~	~	~	~	~	~	
ERDAMHYD-Lawr-N		~	~	~	0.07	~	~	~	~	
ERDAMHYD-Lower-N		~	~	~	0.19	~	~	~	~	
ERDAMHYD-Mala-PN		0.08	~	~	~	~	~	~	~	
ERDAMHYD-Munda-N		~	~	0.53	0.21	~	~	~	~	
ERDAMHYD-Neelum-PN		~	~	0.97	~	~	~	~	~	

Figure 70: Reference Scenario Results – All New Power Plants

Note that any table whose name is highlighted in red has been used for an Update Excel request, and it is important to NOT SAVE the cube layout after adjusting it to examine details in the table.

In addition, the Analytics workbook, discussed in Section IV.D, may also be used to examine the model results and compare successive Reference Scenario runs. In this workbook, single graphs (Reference), comparison graphs (4-scenarios), and difference graphs (from first scenario) are dynamically presented, as shown in Figure 71.



Figure 71: Pak-IEM Analytics Workbook Results

C. Sensitivity Analysis

Once a viable Reference Scenario has been established the model can begin to be used to explore "what-if" scenarios and sensitivity analyses as alternate views of the future of the Pakistan energy sector, as well as to examine in a systematic manner using a consistent framework the response of the energy system to changing circumstances and evolving policies. The Pak-IEM Advisory Committee identified a set of key issues, listed below, that the model is to examine initially.

- Lower and higher economic growth
- Timing of major projects
 - Development of Thar coal reserves
 - Additional nuclear plants
 - Construction and timing of large hydropower plants
 - Large import infrastructure projects for gas and electricity
 - Limits on available capital funds
- Energy security and sustainability
 - Rate load-shedding eliminated
 - Increased use of domestic resources
 - Promotion of renewable energy
 - Promoting energy efficiency and conservation programs
 - Environmental goals (e.g., limits on CO₂)
- Rationalization of energy price subsidies
- Amount and timing of additional oil and gas reserves
- International oil and gas prices

To handle all of these policy scenarios, a special scenario generator file, *Template-Scen_ZPolicyRuns_v###*, supplemented by instances of the Demand, Load-shedding and Sector Prices templates, provides the Planning Team with a consistent approach to building and managing these scenarios to construct policy runs. The initial framework can be readily extended as new issues arise, or VEDA's general scenario files built as needed, as is discussed in the remainder of this section.

Also, as noted earlier, when running policy scenarios that directly impact the power sector, one must remember to review and perhaps adjust the *Buildrates* sheet in the *SCEN_REF-ELC* template to ensure no conflict exists between the limits imposed there and policy being

evaluated (e.g., a to examine maximum renewable electricity the upper default upper limits on wind and solar may need to be raised). In order to make such adjustments, the SCEN_REF-ELC Buildrates sheet should be copied to a new scenario workbook, the non-relevant parts deleted (that is, only keep the constraints that are to be changed in the new workbook) and making the needed adjustments .

A complete set of initial analysis results using Pak-IEM can be found in Pak-IEM Final Report: Volume II – Policy Analysis.

1. Pak-IEM Policy Scenario Generator Workbook

A powerful, flexible, and organized approach to building and managing scenarios has been created for Pak-IEM in the form of the Policy Scenario Generator Workbook, Template-Scen_ZPolicyRuns_v##. The workbook has pre-assembled VEDA/TIMES specifications to enable a series of energy system options and policy levels to be set and combined to perform runs. Figure 72 shows the current list of variants handled by the workbook.

Run Tag	Activated	Status	Run Name	SCEN File Qualifier	Run Label
DL			Low Demand Growth	DEM_PIEMLow	P_DL_0705-01
DM			Medium Demand Growth	DEM_PIEMLow	P_DM_0705-01
TR			No Thar Resource Development	Pol-TharNo	P_DR-TR_0705-01
NF			Nuclear Forced Capacity (Annual)	Pol-NuclearForce	P_DR-NF_0705-01
NM		Not run yet	Nuclear Forced Capacity (Cumulative)	Pol-NuclearCum	P_DR-NM_0705-01
ND			Nuclear Delay	Pol-NuclearDelay	P_DR-ND_0705-01
HD			Hydro Delay (All)	Pol-HydroDelayAll	P_DR-HD_0705-01
HN		Not run yet	Hydro Delay (New)	Pol-HydroDelayNew	P_DR-HN_0705-01
BL	Yes		Budget Level Constraint	Pol-BudgetLimit	P_DR-BL_0705-01
LS			Load Shedding	Pol-LoadshedAdj	P_DR-LS_0705-01
ID			Import Dependency	Pol-ImportRed	P_DR-ID_0705-01
DR		To be added	Oil & Gas Reserve Availability	Pol-DomReserves	P_DR-DR_0705-01
RE			Promotion of Renewable Generation	Pol-RenewableElec	P_DR-RE_0705-01
EE			Energy Efficiency	Pol-Efficiency	P_DR-EE_0705-01
CA			CO2 Annual Cap	Pol-CO2AnnLimit	P_DR-CA_0705-01
CM		Not run yet	CO2 Multiple Year Cap	Pol-CO2MultLimit	P_DR-CM_0705-01
CC			CO2 Cumulative Cap	Pol-CO2CumLimit	P_DR-CC_0705-01
PH			High Energy Price Projection	Pol-PriceHigh	P_DR-PH_0705-01
PL			Low Energy Price Projection	Pol-PriceLow	P_DR-PL_0705-01
SN			Energy Price subsidy Removal	Pol-SubsidiesNo	P_DR-SN_0705-01

Figure 72: Scenario Sheet in the Policy Scenario Generator Workbook

To handle instances of medium/low demand projections, faster/longer timeframe for the elimination of Load-shedding, or adjustments to the Sector Prices (tax/subsidies) refer to the associated files, discussed in sections above with respect to shaping the demands and establishing the Reference Scenario. In the following sections, the remaining policy scenarios are divided into three groups:

- Major Project Limits, where the timing and/or level of specific projects or groups of technologies and explored
- Energy Security and Sustainability, where resource availability, clean energy and environmental issues are adjusted
- Energy Prices, where international (and thereby domestic) prices for oil and gas may be adjusted

The Scenarios sheet reports the instances of Activated options. The way this template workbook should be used is to first save it with a new name reflecting the combination of scenarios to be combined this time, activate them with the appropriate values, and double-

check the list on the Scenarios sheet before resaving and performing the desired sensitivity runs using it. The Run Stamp fields (cells G1:I2) can be used to set the demand/date/instance for each run and is used to construct a suggested run Case name; though the actual name used is up to the analyst and does not have to be tracked here.

The workbook has three worksheets corresponding to the three scenario groups listed above. On any of these sheets, the analyst simply provides a “trigger,” consisting of the word Yes or an appropriate value in row 4 and/or 5 for each option to be activated, as shown in Figure 73. In the figure, we can see that to inhibit Thar coal only a Yes needs to be entered in the drop down menu in cell C5, while for the New Nuclear build a GW level needs to be provided in cell E5. **{Note that when a constraint is not activated "V: *** Inactive ***" will appear above the VEDA update table (turning that update off), while when activated the VEDA update command appears along with the provided value when appropriate.}**

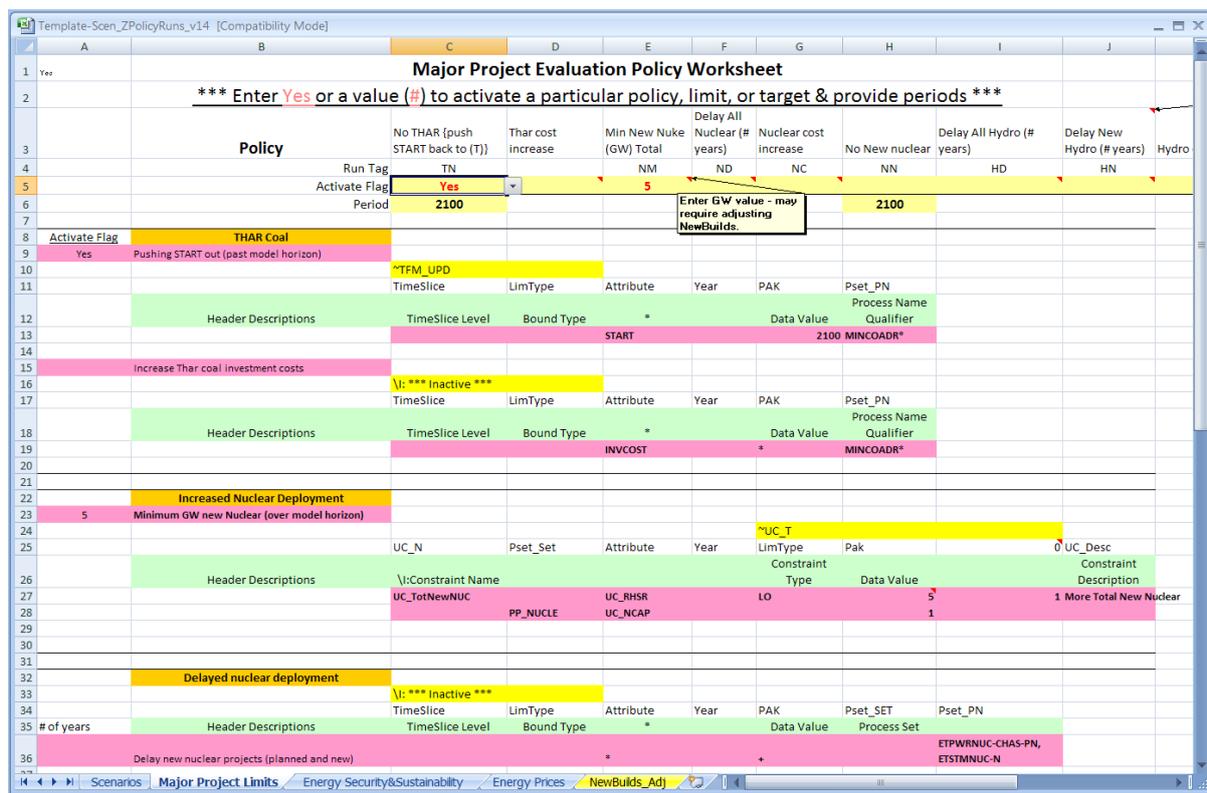


Figure 73: Major Project Limits Policy Scenario Worksheet

The Energy Security & Sustainability worksheet is set up in the same manner, but there are a few special considerations. In the CO2 limit scenario, which caps emissions at some percentage below the Reference case emission levels, relies on data from the **"00_Emissions by Sector"** VBE table to properly set the CO2 cap levels. Likewise, the Promoting Energy Efficiency scenario relies on the **"00_Final Energy by Sector"** VBE table. **Thus, anytime the Reference scenario changes, these tables need to be updated.**

For the Energy Prices worksheet (see Figure 74), the analyst:

- Selects via the drop-down menu in cell D3 whether the Reference, High or Low price trajectory is to be used. The default selection is Reference.
- Adjusts the High/Low oil price trajectories (E8:K9), if desired.

- Adjusts the gas to oil price ratios (R13:S14), if desired.
- Updates the 2007 “seed” values, if the product prices in the BY SUP template have changed.

The resulting values to be fed to the model are displayed in the table below the trajectory growth rate table and then they are formatted for loading into VEDA in a table below it.

		2007	2009	2020	2030	2035	2040	2045	2050	
Crude Oil Price										
	REF (WEO 2009)	\$08/bi	58	60	100	115	124	129	139	149
	HIGH	58	65	120	150	160	170	185	200	
	LOW	58	60	90	100	105	110	115	120	
Growth rate										
	REF	1.00	1.03	1.71	1.97	2.12	2.21	2.38	2.55	
	HIGH	1.00	1.11	2.06	2.57	2.74	2.91	3.17	3.43	
	LOW	1.00	1.03	1.54	1.71	1.80	1.88	1.97	2.06	
		\$/GJ								
	2007	2009	2020	2030	2035	2040	2045	2050		
19	Imp. Crude	IMPOILCRDI	10.1	10.34	17.23	19.81	21.30	22.18	23.90	25.66
20	Dom. Crude	MINOILCRDD-Ball	7.0	7.24	12.06	13.87	14.91	15.53	16.73	17.97
21		MINOILCRDD-NWFI	7.0	7.24	12.06	13.87	14.91	15.53	16.73	17.97
22		MINOILCRDD-Punl	7.0	7.24	12.06	13.87	14.91	15.53	16.73	17.97
23		MINOILCRDD-Sinl	7.0	7.24	12.06	13.87	14.91	15.53	16.73	17.97
24	Import POL	IMPOILHSD	17.1	17.55	29.25	33.64	36.17	37.67	40.58	43.58
25		IMPOILHFO	10.6	10.88	18.13	20.85	22.42	23.35	25.15	27.01
26		IMPOILLDO	15.4	15.83	26.38	30.33	32.61	33.96	36.58	39.29
27		IMPOILKER	18.6	19.12	31.86	36.64	39.39	41.03	44.20	47.47
28		IMPOILGSL	18.0	18.51	30.86	35.48	38.15	39.73	42.80	45.96
29		IMPOILAVG	17.7	18.15	30.25	34.79	37.39	38.95	41.95	45.06
30		IMPOILLPG	14.5	14.91	24.84	28.57	30.71	31.99	34.46	37.01
31	Export POL	EXPOILHSD	-8.5	-8.78	-14.63	-16.82	-18.08	-18.83	-20.29	-21.79
32		EXPOILNAP	-9.9	-10.18	-16.96	-19.51	-20.97	-21.84	-23.53	-25.27
33		EXPOILGSL	-9.0	-9.26	-15.43	-17.74	-19.07	-19.86	-21.40	-22.98
34		EXPOILAVG	-8.8	-9.07	-15.12	-17.39	-18.70	-19.47	-20.98	-22.53
35		EXPOILKER	-9.3	-9.56	-15.93	-18.32	-19.70	-20.51	-22.10	-23.73
36		EXPOILLDO	-7.7	-7.91	-13.19	-15.17	-16.30	-16.98	-18.29	-19.65
37		EXPOILLPG	-7.3	-7.45	-12.42	-14.29	-15.36	-15.99	-17.23	-18.50
38		EXPOILHFO	-5.3	-5.44	-9.07	-10.43	-11.21	-11.67	-12.57	-13.51

Figure 74: High/Low Energy Prices Policy Scenario Worksheet

With regard to many of the scenarios it is important to keep in mind that in the some of the Reference Scenario tailoring templates there are constraints on the power sector build rates by fuel group and controls on degree of fuel switching permitted that may need to be adjusted for certain scenarios to work.

2. Additional Alternative Scenarios

The tools and techniques employed to build the Pak-IEM Scenario Generator Workbook discussed above can obviously be expanded to add additional control areas, VEDA data blocks, and Scenario summary sheet entries as the need arises. For more sophisticated or single time scenarios the VEDA Attribute Master can be used to build custom scenario files from scratch. In addition, it may be necessary to supplement the Reference set of new technologies with additional options, such as hydrogen or biofuel sub-systems, which requires adding to or making a new NewTech SubRES. Each of these is discussed in this section.

2.1. Using the VFE Attribute Master

The VFE Attribute Master serves several useful purposes, as show in Figure 75, by listing all the attributes managed by VFE, indicating the required index qualifiers (with their defaults), and interpolation rule employed. The attributes listed to the left are the TIMES parameters while for the most part the Alias list is composed of the corresponding VEDA parameters.

Attribute	Years	Process	Commodity	TimeSlice	LimType	Currency	Stage	SOW	Other_Indexes	Alias
ACT_BND	Yes			ANNUAL	UP					BOUND(BD)/BNDACT/ACTBND/BOUND(BD)Or
ACT_COST	Yes					CUR				VAROM/ACTCOST
ACT_CUM	Yes				UP					CUM/BNDCUM
ACT_EFF	Yes			ANNUAL					CommGrp	
CAP_BND	Yes				UP					BOUND(BD)/BNDCAP
CCAP0	NO									
CCAPM	NO									
CEFF	Yes			ANNUAL						CEFFICIENCY
CEFF	Yes		Def Out	ANNUAL						CEFF-0
CEFF	Yes		Def In	ANNUAL						CEFF-1
CLUSTER	NO								TimeSlice2	
CM_CO2GTC	NO									
CM_CONST	NO									
CM_EXOFORC	Yes									
CM_HISTORY	Yes									
CM_LINFOR	Yes									
CM_MAXC	Yes									
CM_MAXCO2C	Yes									
COM_AGG	Yes								Commodity2	CAGG
COM_BNDNET	Yes			ANNUAL	UP					ENV_BOUND(BD)/ENVBND/CBNDNET
COM_BNDPRD	Yes			ANNUAL						CBNDPRD
COM_BPRICE	Yes			ANNUAL		CUR				MED-DMBPRICE/CBPRICE
COM_CSTNET	Yes			ANNUAL		CUR				ENV_COST/ENVCOST/CCSTNET
COM_CSTPRD	Yes			ANNUAL		CUR				CCSTPRD
COM_CUMNET	Yes				UP					ENV_CUMMAX/ENVCUM
COM_CUMPRD	Yes				UP					
COM_ELAST	Yes			ANNUAL						MED-ELAST(BD)/CELAST
COM_ELASTX	Yes									ELASTX
COM_FR	Yes									FR(Z)/Friction
COM_IE	Yes			ANNUAL						TE(ENT)/TE(MAT)
COM_LIM	NO									
COM_PEAK	NO									
COM_PKFLX	Yes									PKFLX
COM_PKRSV	Yes									HRESERV(E)RESERV
COM_PROJ	Yes									DEMAND
COM_STEP	NO									MED-STEP(BD)/CSTEP
COM_SUBNET	Yes			ANNUAL		CUR				CSUBNET
COM_SUBPRD	Yes			ANNUAL		CUR				CSUBPRD
COM_TAXNET	Yes			ANNUAL		CUR				CTAXNET
COM_TAXPRD	Yes			ANNUAL		CUR				CTAXPRD
COM_TSL	NO									

Figure 75: VFE Attribute Master

However, besides basic information provided by the Attribute Master, it may also be used to create an initial VFE load sheet ready for the specification of the appropriate qualifiers and importing. There are two layouts that may be set up:

- VFE flexible input table (~FI_T, such as that used in the BY and SubRES - which it is recommended to work with)
- VFE Scenario Insert/Update, shown below

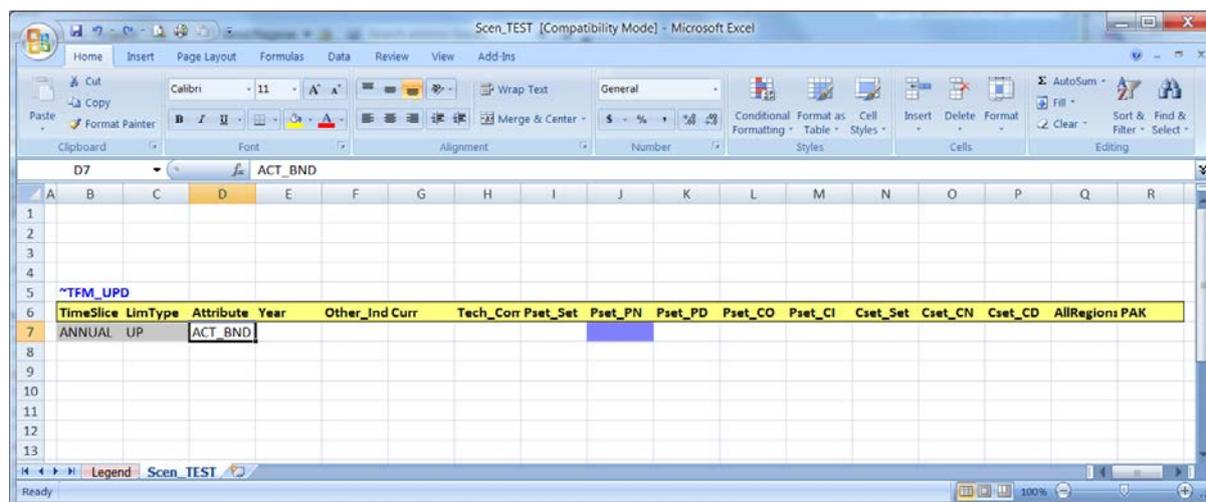


Figure 76: VEDA Flexible Update/Insert Table

To request a VFE Scenario table an existing Scen file needs to exist. Once the parameter(s) desired are checked and the INS/UPD button hit the resulting worksheet will be laid out for the Attribute indicating required qualifier information (timeslice, limtype with their defaults) and list all the possible rule components by which the desired model component (for ACT_BND that would be the process or group of processes to have a bound applied). {Note that when YEAR is not specified for a time dependent parameter it defaults to the 1st period.}

As seen in Figure 76 there are essentially two groups of criteria specifications, the Pset and Cset for process and commodity related rule specification, where the _suffice means:

- Set – list of process or commodity sets
- PN/CN – list of process or commodity item names masks
- PD/CD – list of process or commodity description masks
- CI/CO – I/O input/output flow indicator for Tech_Comm

The actually value to be assigned to the qualifying items is provided in either the AllRegions or PAK columns. Note that "*" wildcards are permitted in P/Cset fields, as well as "-" for NOT. A list of expressions separated by commas "," may be provided for any combination of fields corresponding to the "rule" that is to be followed to identify the qualifying model components. This is clearly a powerful facility that needs to be used carefully, and checked out in VFE Browse to see that the desired results are obtained.

One tricky aspect of working with the VFE INS/UPD facility is that the user has full responsibility to ensure that INS inserts only new entries and UPD changes only existing information for all qualifying indexes (including year/bound type/timeslice). The SYNC operation now checks to make sure this rule is strictly adhered to, reporting any conflicts or ignored entries in the Log.

2.2. Adding New Technologies {Augmenting the SubRES}

Any time a new option needs to be added to Pak-IEM it is necessary to augment the RES by adding any new processes and commodities to the future options available to the model by means of the *SubRES_NewTechs*. For a new process, this can be done by replicating an existing new option on the corresponding (or new (copied)) load sheet by simply copying a row (or more if dual fueled/output) in the ~FI_T table specification area, and doing the same in the ~FI_Process declaration block. If the technology also introduces the need for new commodities, then a ~FI_Comm declaration will be needed for them as well.

Once specified and imported into VFE the new option should be examined robustly (via RES and/or Process Master for topology, as well as Browse for actual data).

V. Examining Pak-IEM Model Result

TIMES model results are managed comprehensively by VEDA_Back-End (VBE). VBE is a remarkably simple yet extremely powerful system based upon these core aspects and features:

- A detailed set of TIMES model results handled as Attributes, with all manipulation and aggregation handled by VBE.
- **Attributes** are naturally indexed by components of the RES (commodities and technologies), the model timeframe (periods, timeslices, vintage) and most importantly the Scenario.
- The ability to define **Sets** for the RES components based upon rule conditioned by name/description/topology criteria, which then serve as aggregation levels in the Tables.
- Assembly of the Attributes, conditioned by the Sets and/or specific criteria for some index, into **Tables**.
- The construction of dynamic data **Cubes** (multi-dimension pivot tables) that permit easy manipulation and automatic aggregation of the Tables.
- An update facility that permits the updating of exported Cubes to **Analytics** Excel workbooks, where multi-case graphing of scenarios is interactively supported.

In addition to these central themes, VBE also provides:

- Full-functioned **Unit** conversion.
- An override qualification by a **Global Filter** applied to each table request, which is particularly useful for switching Scenarios.
- The ability to group tables into **Reports**.

Each of these features and the overall philosophy for working with VBE is discussed in the rest of this section.

A. Connecting VBE to Model Results

The Case Manager of VFE points to the GAMS Work Folder (GAMS_WrkPIEM), which is then the folder in which the model runs results are actually saved. So, VBE needs to be connected to the same folder in order to access the model run results. To make this link use the VBE Results/Import command [or hit [F7]/ ] to be presented with the list of model runs VBE can see according to the current folder list. See Figure 77. If you don't see your run listed then you're not yet linked to the GAMS Work Folder, which can be done by clicking the Manage Input File Locations button at the bottom left of the Import/Archive window and navigating to the \VEDA\VEDA_FE\GAMS_WrkPIEM folder.

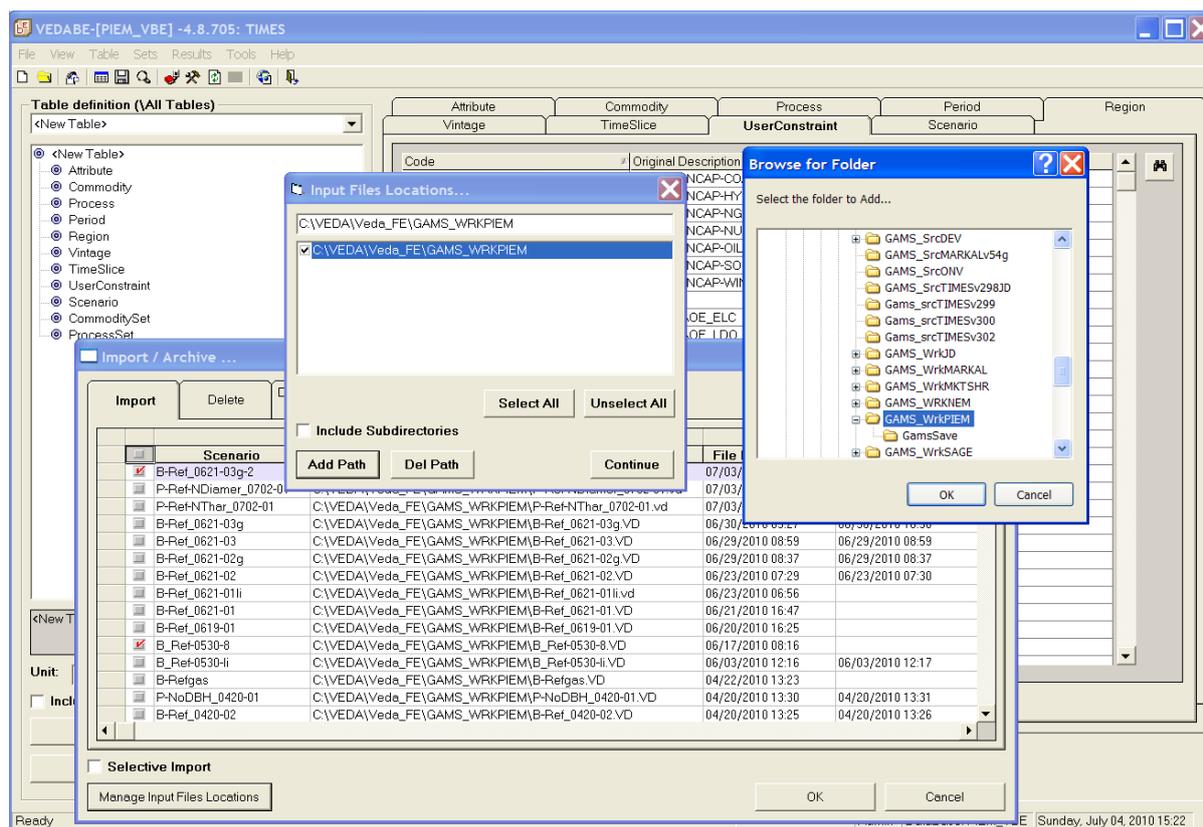


Figure 77: Linking VBE to the GAMS_WrkPIEM Folder

Once the desired runs are seen, simply check them for importing and click the OK button. Note that if a run is already loaded into VBE and has been rerun (has a newer date than the date imported) it will be automatically preselected.

B. VBE Basics

This section presents a concise overview of the most often used aspects of VBE, with Section IV.C providing a specific discussion related to Pak-IEM.

1. Main Form Layout and Content

The main form of VBE is the table specification and selection interface as shown in Figure 78. It is divided to two forms. The left (Table definitions) side shows the current table specification, the combination of index criteria, either sets or individual items (e.g., Attributes, Process/Commodity items or sets) that define that table. For any table dimension which has no qualifiers specified, all information for that dimension will be retrieved. The right side shows the index qualifier tabs, which show all the qualifies available for that tab (dimension). The sets or elements currently specified for the selected table will be highlighted.

To select an existing table simply pull down the Table Definition List and pick the desired table. In Figure 78, we can see that *00_EnergyBalance-FinalEnergybyFuel* table comprises the Attribute VAR_Fin (corresponding to the consumption commodity for a technology), the Commodity Sets for each of the main fuel groups, and Process Sets grouped by end-use sector. *{The table name is shaded red because the table has been used in an Update Excel (see Section V.D.3).}* In Figure 78 we can see the Scenario tab showing all the scenarios that are currently loaded in the VBE database.

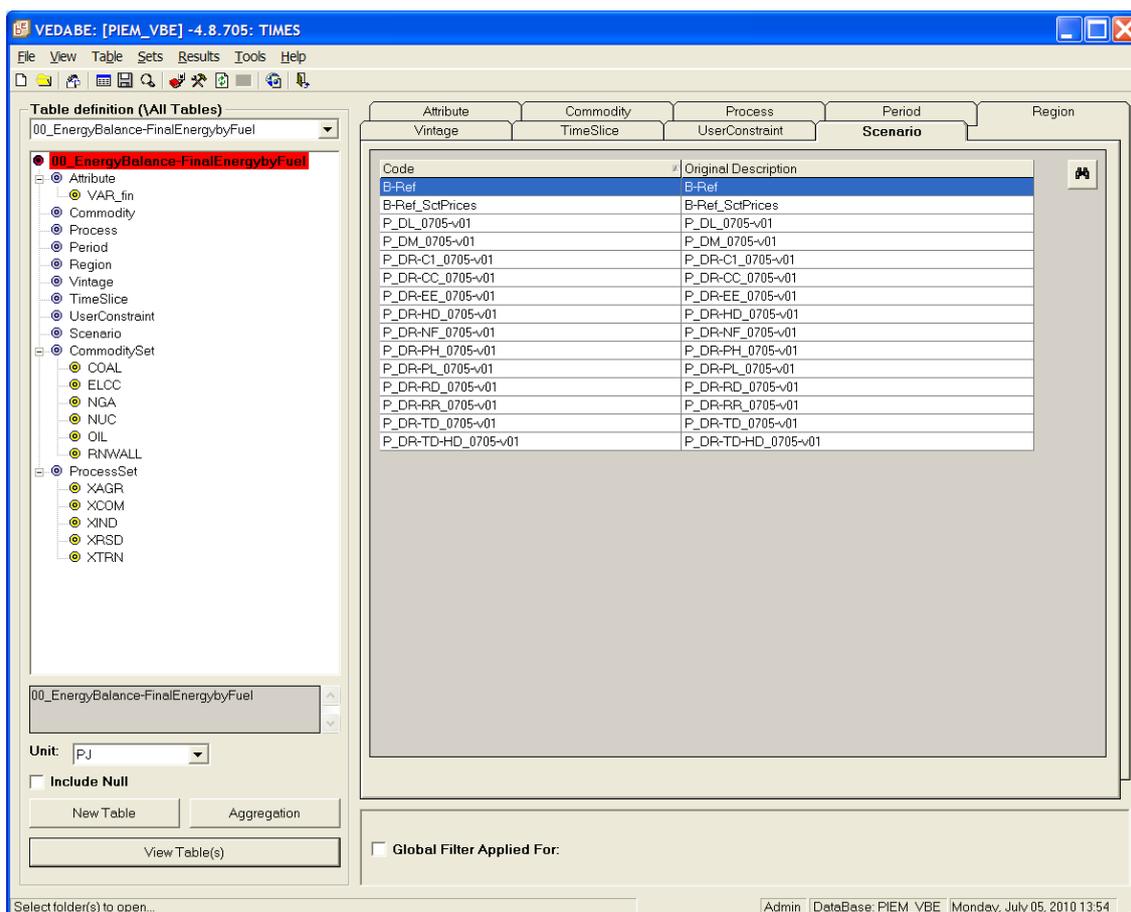


Figure 78: VBE Table Specification and Selection Interface

2. Attributes

As already mentioned, the Attributes correspond to the actual results from each model run. Figure 79 shows the entire Attribute list. The most often used attributes include:

- VAR_Fin – consumption level of each commodity by a process
- VAR_Fout – production level for each commodity by a process
- VAR_Act – total output from a process
- VAR_Ncap – incremental capacity additions (new builds)
- VAR_Cap – total installed capacity in place in a period
- ObjZ – total discounted system cost
- Cost_* – various costs (e.g., investment, supply, O&M) calculated by the TIMES report writer
- *M – the marginal cost associated with commodities (e.g., fuel price, carbon value) and technologies (e.g., new investment, capacity, activity)

The Attributes that begin with VAR/EQ correspond to raw model results whereas all the others (besides ObjZ) are calculated by the TIMES report writer.

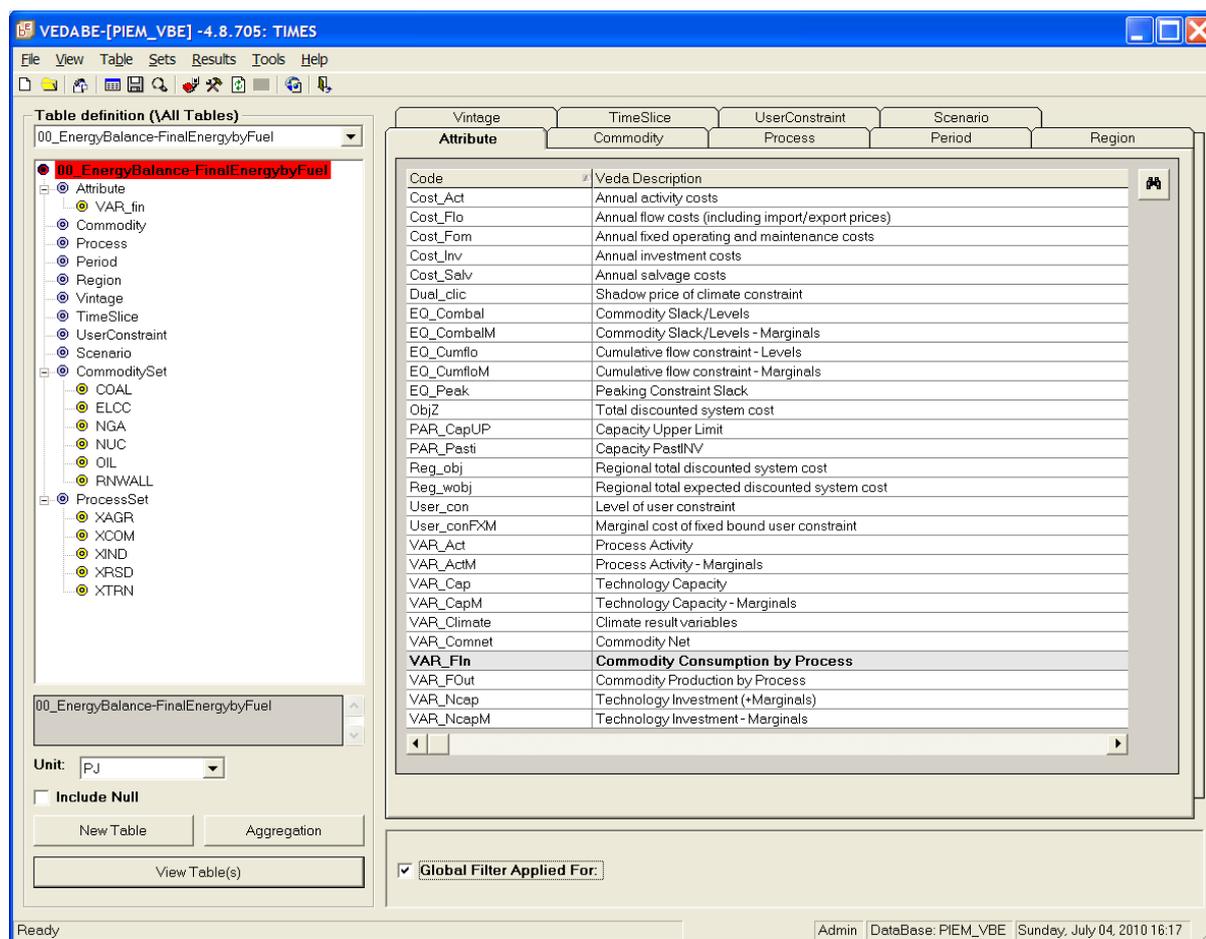


Figure 79: VBE Attribute List

3. Sets

As already mentioned, Sets are groupings of like Commodities or Processes. Sets either come predefined with TIMES (e.g., NRG-energy, MAT-material, ENV-emissions) or are assembled by the analyst. Looking at the *00_EnergyBalance-FinalEnergybyFuel* Process tab, Figure 80, the first thing we see is that the tab is split into a Set specification area (up top) and an item instance list below. In the Set area we can see four (4) shadings:

- white – TIMES core Set
- grey/bold – Set is selected in the current table definition
- dark blue – user-defined Set
- light blue – user-defined Set that is based upon another user defined set (that is nested 1-level)

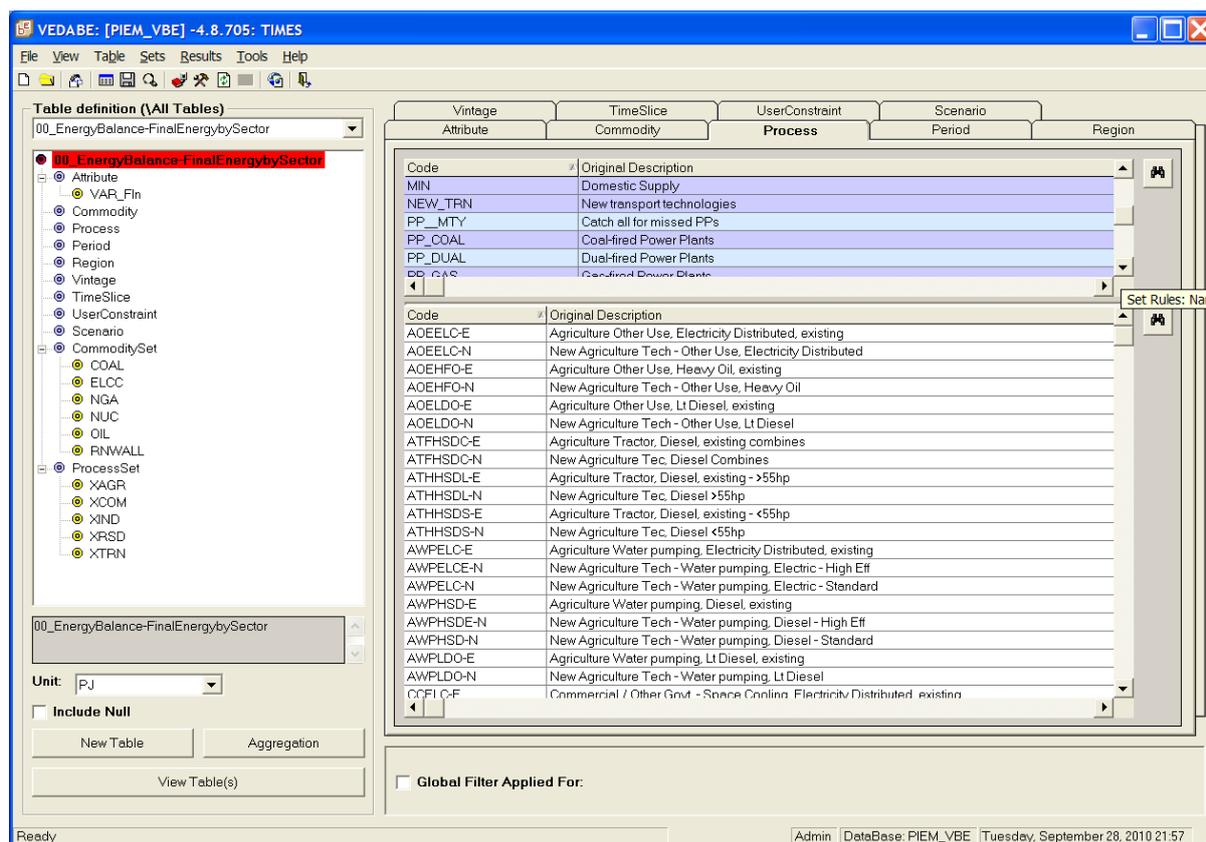


Figure 80: VBE Process Tab

Sets are constructed by two main methods. A new set can be created by means of the Sets/New Sets command. Existing sets can also be modified (and new sets constructed from the modified set definitions) by means of the Sets/Edit Sets command. In either case, note that the sets form is used for both Commodity sets and Process sets, as specified in the drop down menu in the upper left.

To establish a new set definition, first indicate if you are editing Commodity sets or Process sets, as specified in the drop down menu in the upper left. Then identify which existing sets should be included or excluded. In Figure 81, the TIMES predefined set ELE was selected for inclusion, which is the set of all power plants. The desired set – for this example – is the set of planned new hydropower plants. Further specification to create this set is accomplished by means of text strings, which, if contained in the process name or description, will include (or exclude) the technology. More than one text string can be specified, separated by a comma, if necessary to uniquely identify the subset of interest. One can also specify sets according to input and output commodities masks of processes. Note that these sets may be qualified by being a subset of a main TIMES set, or another user defined set 1-level deep. Once the New Set definition is entered, clicking the Shortlist button will populate the right side of the form with the current entities meeting the criteria.

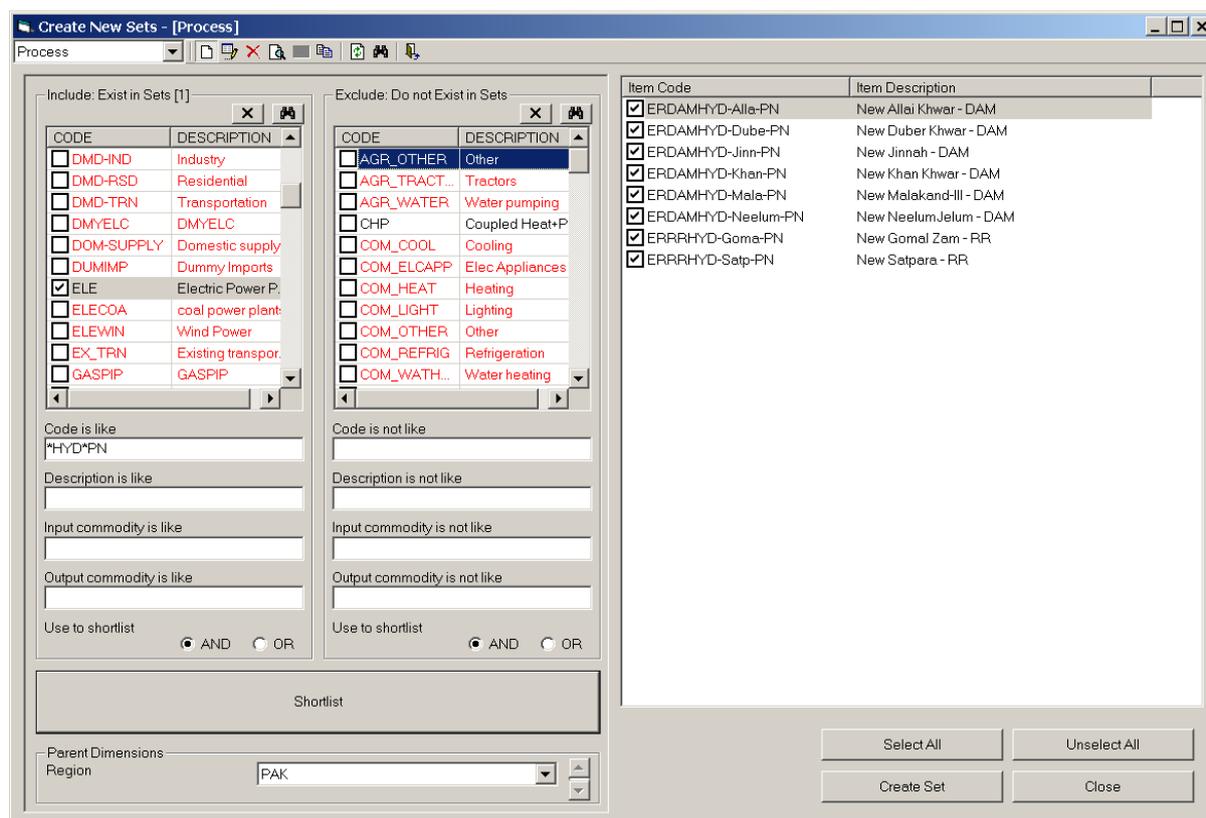


Figure 81: Creating a New Set in VBE

To edit an existing set, first check that the Commodity/Process group is active and then select that set in the Set Name menu box. In Figure 82, the XRSD process set has been selected, which is used in the *00_EnergyBalance-FinalEnergybyFuel* table. The rule for the XRSD Process set is based on the premise that all fuels feeding the Residential sector pass through so-called sector collection processes named XRSD<fuel>.

To edit this set, the Edit set button must first be clicked. That will activate the form and allow any of the include/exclude sets to be modified, or any of the text strings to be modified. Clicking the Shortlist button will repopulate the right side of the form with the current entities meeting the criteria. Once the set is properly defined hit the Update Set button and confirm or adjust the set name. *{Note that if a new name is provided the old set is still retained, and may need to be deleted if no longer needed.}*

The key to fully exploiting this powerful feature of VBE is the strict and careful adherence to naming conventions, both in the item names and the descriptions, as laid out in detail for Pak-IEM in the Pak-IEM Final Report: Volume I – Model Design.

Note that after returning to the VBE Table Definition form, the rule for each Set can also be seen by simply hovering over the Set name on the top part of the Commodity/Process tab.

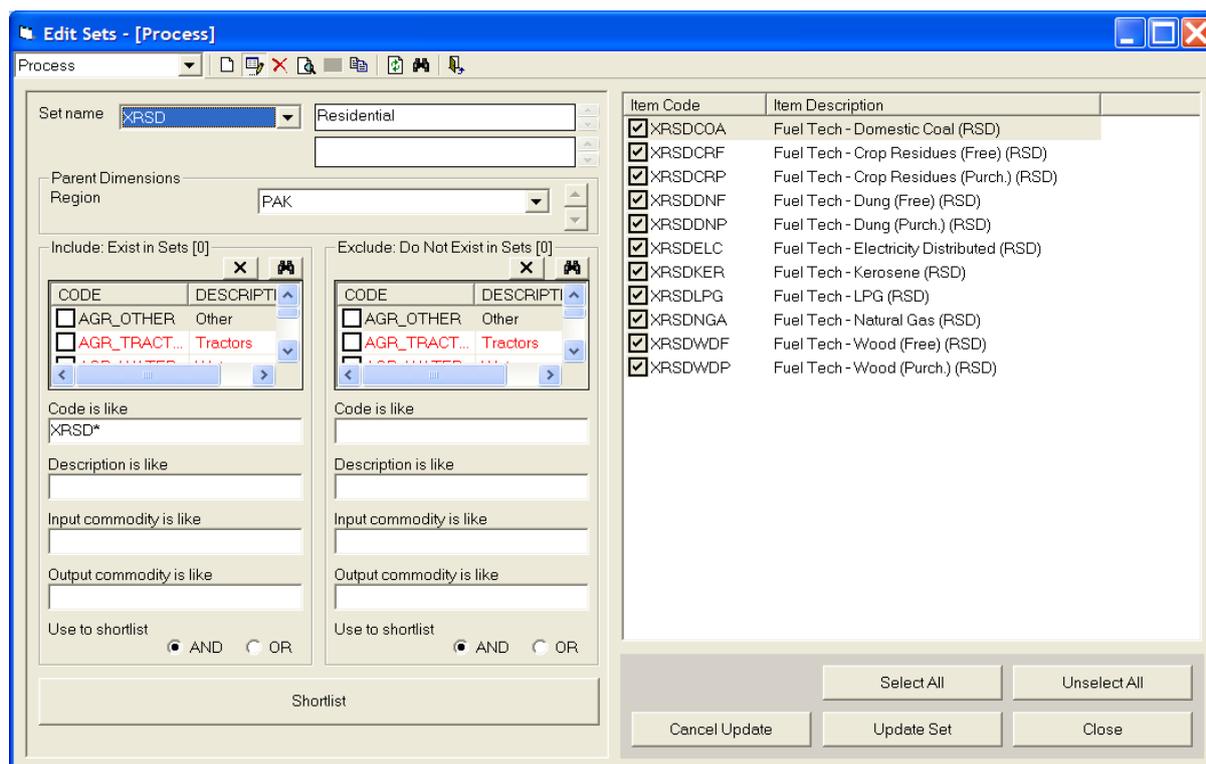


Figure 82: Editing an Existing Set in VBE

One extremely useful aspect of the VBE Sets is that they can be connected with VFE via the VEDA_SnT file to allow VFE-Browse/RES/etc to use the same nested custom Set definitions to limit selection lists. Note that the SnT file may be exchanged (carefully) between users when new sets or tables are added by either closing VBE and simply replacing the SnT file in the PIEM_VBE folder, or using the VBE Sets/Import/Access option by pointing to the new VEDA_SnT and selecting the Sets/Tables you want to bring in (replacing any with the same name in the current database).

4. Tables

Tables are the collections of relevant information that are presented as a dynamic pivot table in the VBE Cube viewer. There are three ways to select tables for viewing:

- **Interactive.** This is the default mode available on opening VBE, where one table at a time is selected and the corresponding table definition shown (what we've been seeing till now). This mode can be selected via the View/Execution Mode menu.
- **Batch.** In this mode, all tables are shown and any number can be checked for presentation as cubes. This mode is also selected via the View/Execution Mode menu.
- **Table Master.** Allows the Analyst to group tables into folders and view all or only selected tables in the folder in the cube view. The Table Master can be selected from the Table/Table Master menu command as shown in Figure 83. The folders defined via Table Master can also be used to modify the list of tables that are viewed in Interactive or Batch modes. This feature of the Table Master is activated by clicking on the Table Definition bar above the table selection window, as shown in Figure 84. By selecting one (or more) of the folders available in Table Master, the Interactive and Batch lists will be limited to just those tables. *Note that the table list will be shaded yellow when other than the All Tables root folder is selected.*

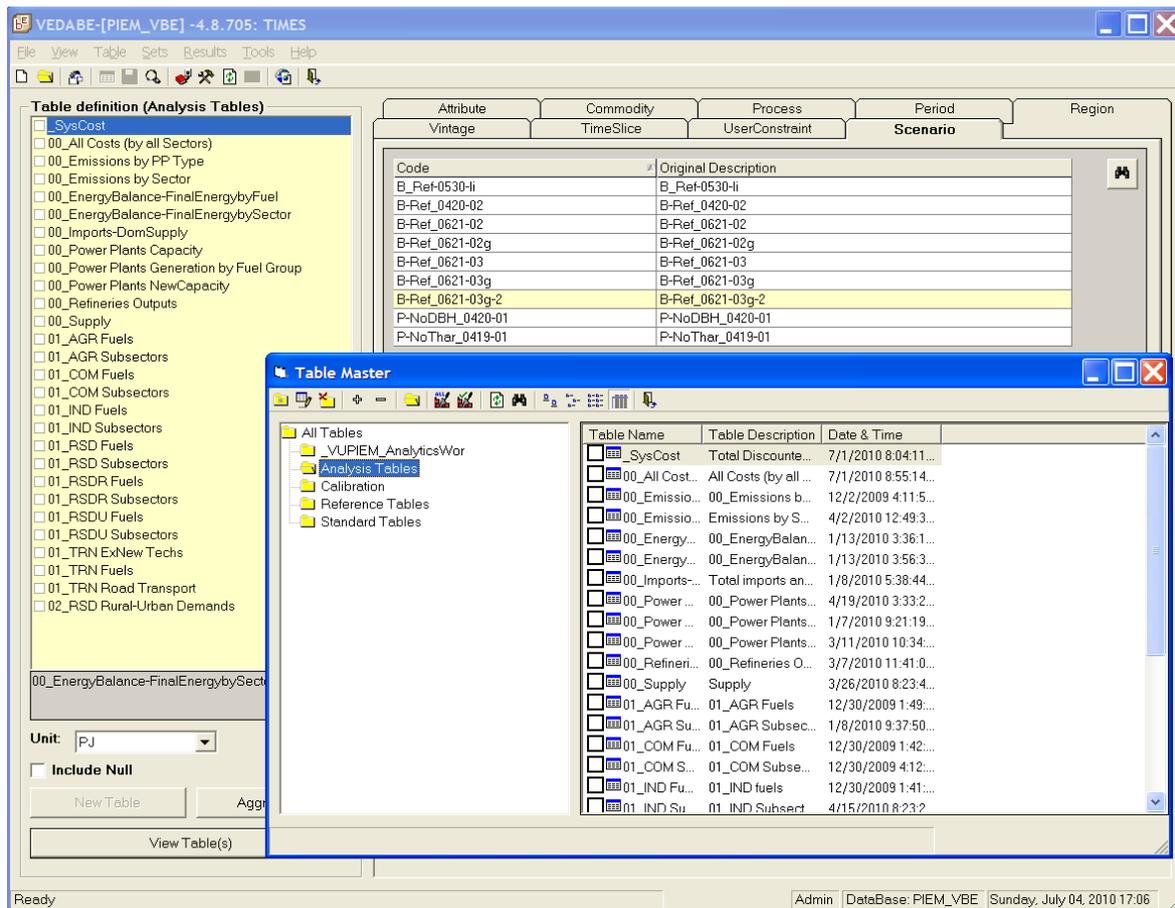


Figure 83: VBE Table Master

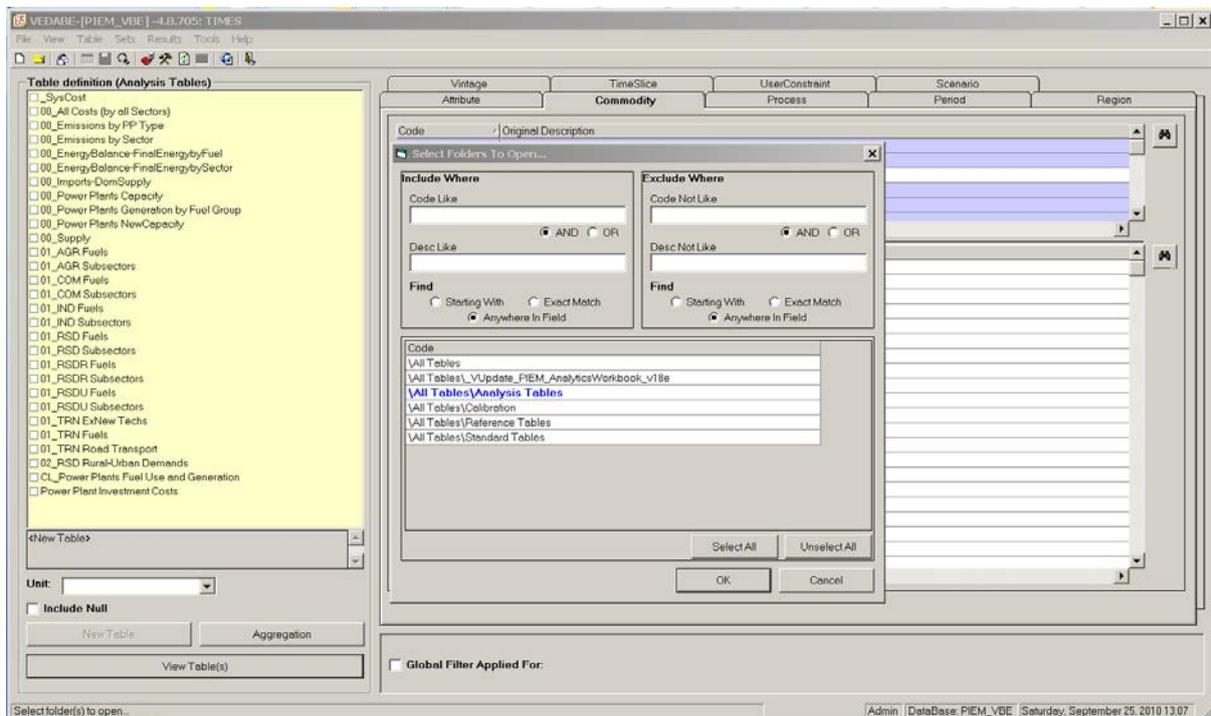


Figure 84: Selecting Specific Folders from VBE Table Master

5. Cube View and Manipulation

Tables are the collections of relevant information that are presented as a dynamic pivot table in the VBE Cube viewer. Besides simply displaying the entities that have been included in the table definition, either individually or by means of Sets, the real heart and power of VBE comes from combining the Set selection criteria with the flexible table specification to present tables in dynamic data Cubes.

Cubes are multi-dimensioned pivot tables that enable the analyst to scope in/out of the data to digest what's happening in the model runs. The key features of the Cubes are:

- Drag/drop of dimensions on/off of the cube (with associated dynamic aggregation of any removed index). In Figure 85, the Process set dimension has been dragged into the initial display of the 00_EnergyBalance-FinalEnergybySector table (top view) to give the new view shown below.
- Repositioning of the row indexes (e.g., drag Scenario to the right to see how each component changes across multiple scenarios).
- Pull-down list associated with any index elements that can be use to remove (temporarily) any element of the list. (Note that control click will unselect/select all elements.)
- Easy requesting of totals, descriptions, and hiding of details via a context sensitive right-mouse menu.
- Unit conversion through the Active Unit menu above the cube.
- Selective (and wholesale) copying to Excel.

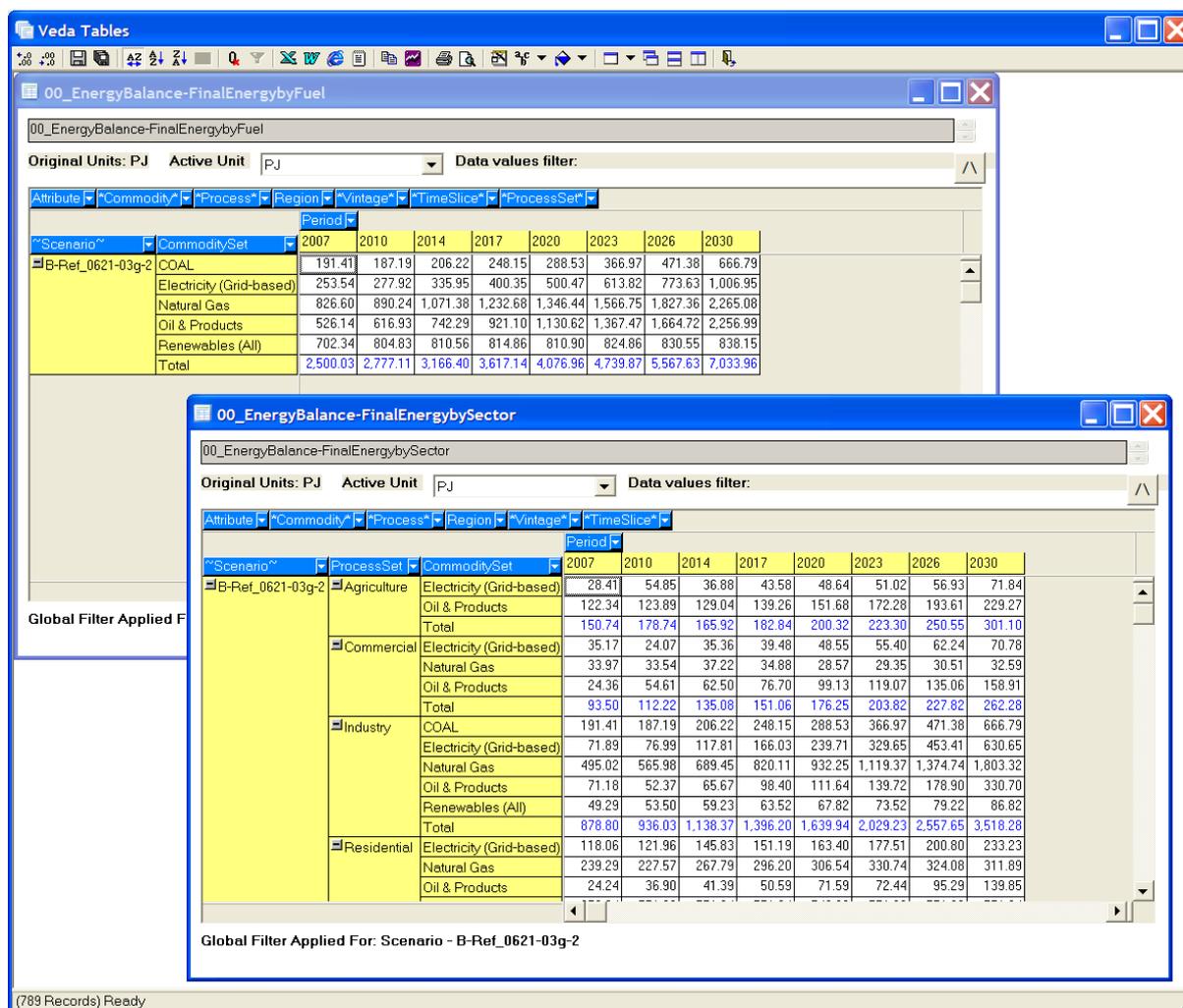


Figure 85: Example of VBE Dynamic Cube Change

In addition to the facilities just mentioned, tables, or selected (highlighted) areas of tables

can be quickly graphed by clicking the  button, as shown in Figure 86. However, a much more robust and quality graphing facility can be realized by linking the VBE cubes with the Pak-IEM Analytics workbook, where a set of most often needed graphs have been pre-established and can be refreshed by scenario dynamically by means of the Update Excel facility discussed below and in Addendum A.

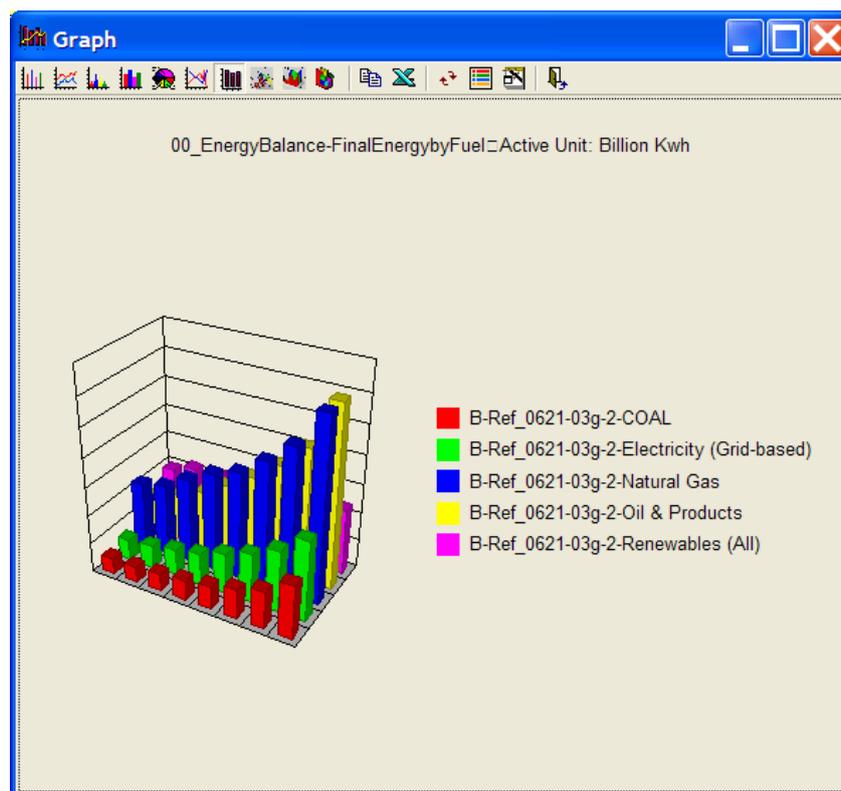


Figure 86: Quick Chart Option for VBE Tables

6. Units Management

One of the more critical needs when communicating model results with policy-makers is getting results into appropriate units. While this seems obvious it can also be quite annoying. However, VBE does a full-featured job of supporting unit conversion by means of:

- The Tools/Units facility where the individual units are named and their conversion factors for other compatible units provided (see Figure 87).
- Specifying the model units associated with the attribute comprising each table in the Unit specification pull-down near the bottom of the Table Definition view (See Figure 80). These original units will be saved as part of the table definition [Note that care needs to be taken when Attributes are mixed in a single table as they may be in different units. This is the analyst's responsibility and no Unit should be provided for such a table.]
- The unit in the cube view for any table can be switched via the Active Units menu above the cube. If the table is saved from this cube view, it will be saved with the Active units so that when displayed in the future the Active units will be used. [Note that VBE displays the original units in the table definition as a reminder, converting on the fly when assembling the cube.]

In addition to Create/Edit/Delete Units, the Tools/Units facility also allows the set of Units for the model to be exported and imported, which allows sharing of updated sets of Units between Analysts.

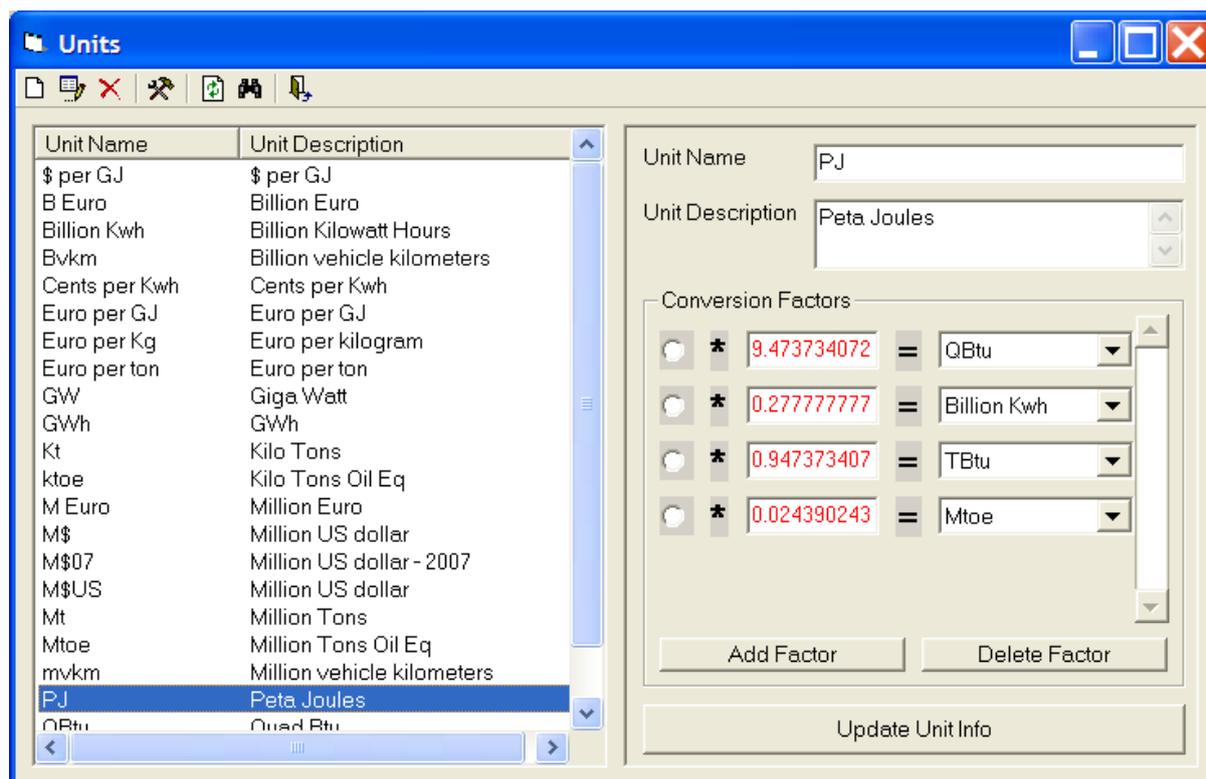


Figure 87: VBE Unit Conversion Definition Window

7. VBE Update Excel Facility

VBE has a powerful facility that allows the Table data to be exported to an Excel workbook, where the analyst can set up manipulations and graphs that further facilitate the understanding and communicating of model results. Details with respect to the Pak-IEM Analytics workbook, which uses the tables in the Table Master folder labeled Analysis Tables to populate a series of VEDA_Dump tables and a set of associated comparison graphing sheets, may be found in Section IV.D and Addendum A.

The basic premises/procedures behind VBE Update Excel facility are:

- Tables with appropriate units are defined
- The tables to be exported are laid out in their desired orientation and formatted appropriately
- Tables are exported to an Excel workbook with properly formatted destination tables
- All desired graphs and repeated operations are created in the workbook
- The VBE scenario global filter is set to those scenarios to be updated

The command Tools/Update Excel file is invoked to update any/all of the tables in the destination workbook, and the sub-menu will allow All Tables or Selected Tables to be chosen. In either case, VBE will open a navigation window to allow the analyst to navigate to and select the Excel file for updating. ***This file must be closed for the Update Excel operation to proceed properly.*** If All Tables was selected, VBE will begin the update once the Excel file is opened in the navigation window. If Selected Tables was selected, a Table Selection window will open as shown in Figure 88. Check the tables to be updated and click OK to start the update process.

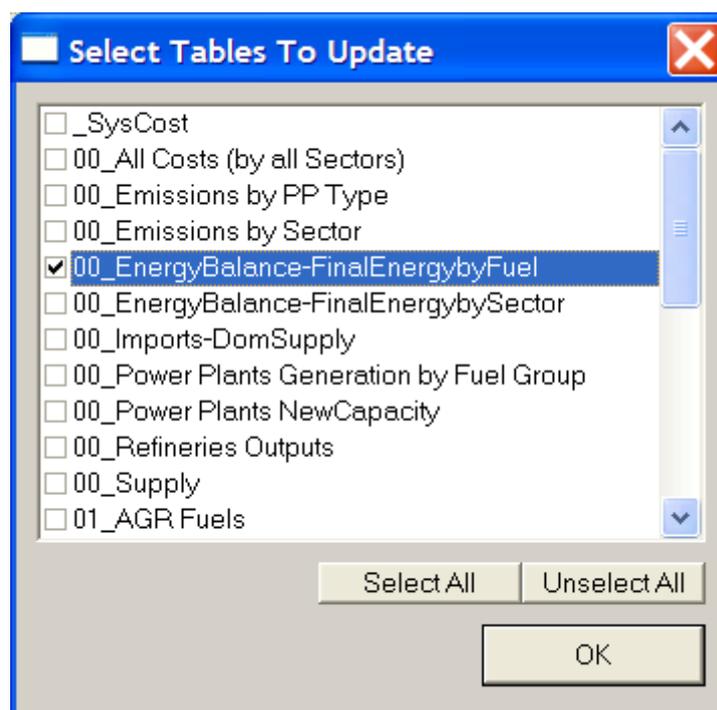


Figure 88: VBE Update Excel File Table Selection Window

Critical to the Update Excel facility is the need for the saved tables to have their names, units, and layouts correspond exactly to the names, units, and layouts of the tables in the target Excel workbook. This is why tables are highlighted in red by VBE once used to by the Update Excel facility. It is also necessary to make sure that any Global Filter for Scenarios matches the scenarios found in the Excel workbook, otherwise the Update Excel facility will delete the values associated with any scenarios in the workbook but not selected by the Global Filter during the update process.

During the Update Excel operation, VBE will be interacting with Excel, and in order to avoid conflicts with the VBE operation, ***the analyst should not open or process other Excel files while VBE is running the Update Excel operation.***

After completion of the Update Excel operation, the analyst can open the Excel workbook to view the update results, as shown in Figure 89. When the Update Excel operation is successful the cells updated in the workbook (all on the VEDA_Dump sheets) are shaded yellow. Any rows in the workbook not found by VBE will be tagged red, and any VBE table entries not found in the workbook will be written to a log, along with any table layout issues. VBE will prompt the analyst to view these log files, which should be reviewed to ensure that all tagged discrepancies are understood.

Again, see Section D below and Addendum A for a full discussion of the PIEM Analytics workbook and its operation.

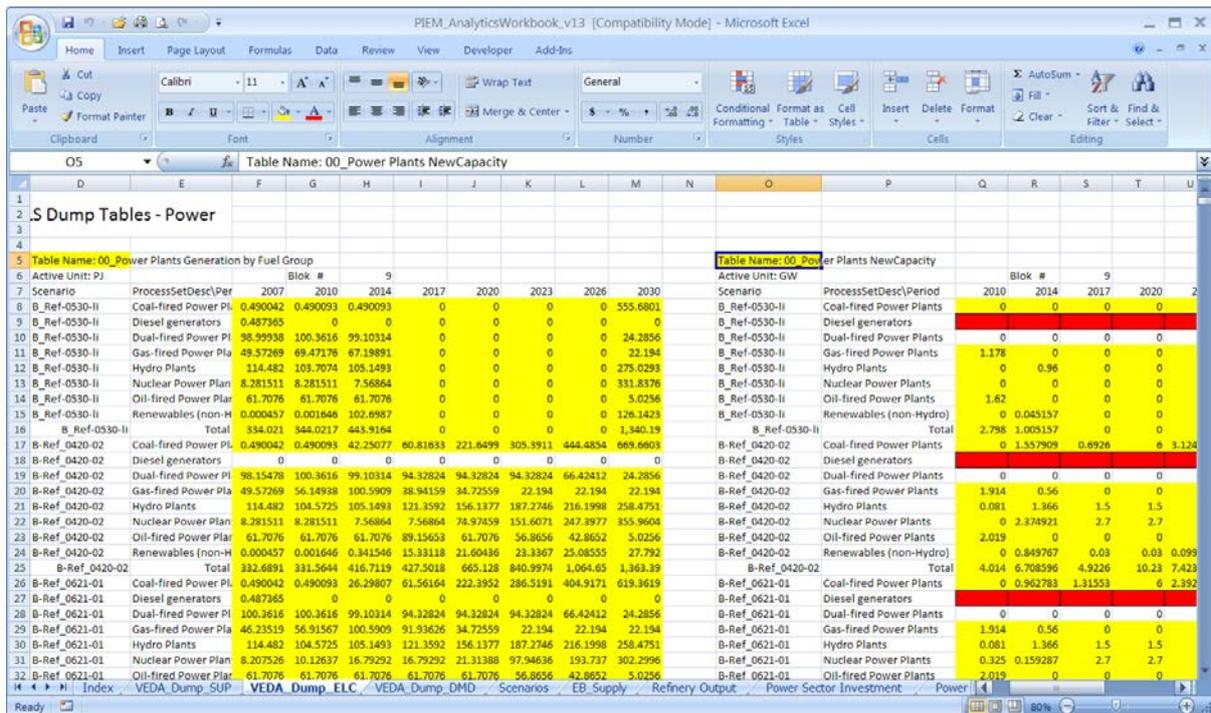


Figure 89: Update Excel Workbook

8. Other Useful VBE Features

There are several other useful VBE feature discussed briefly here, but the user is encouraged to carefully review the VedaSupport website documentation and join the VEDA Forum.

8.1. Search Engine

When looking to “zero in” on a particular model component, or group of items, the [F3/ 

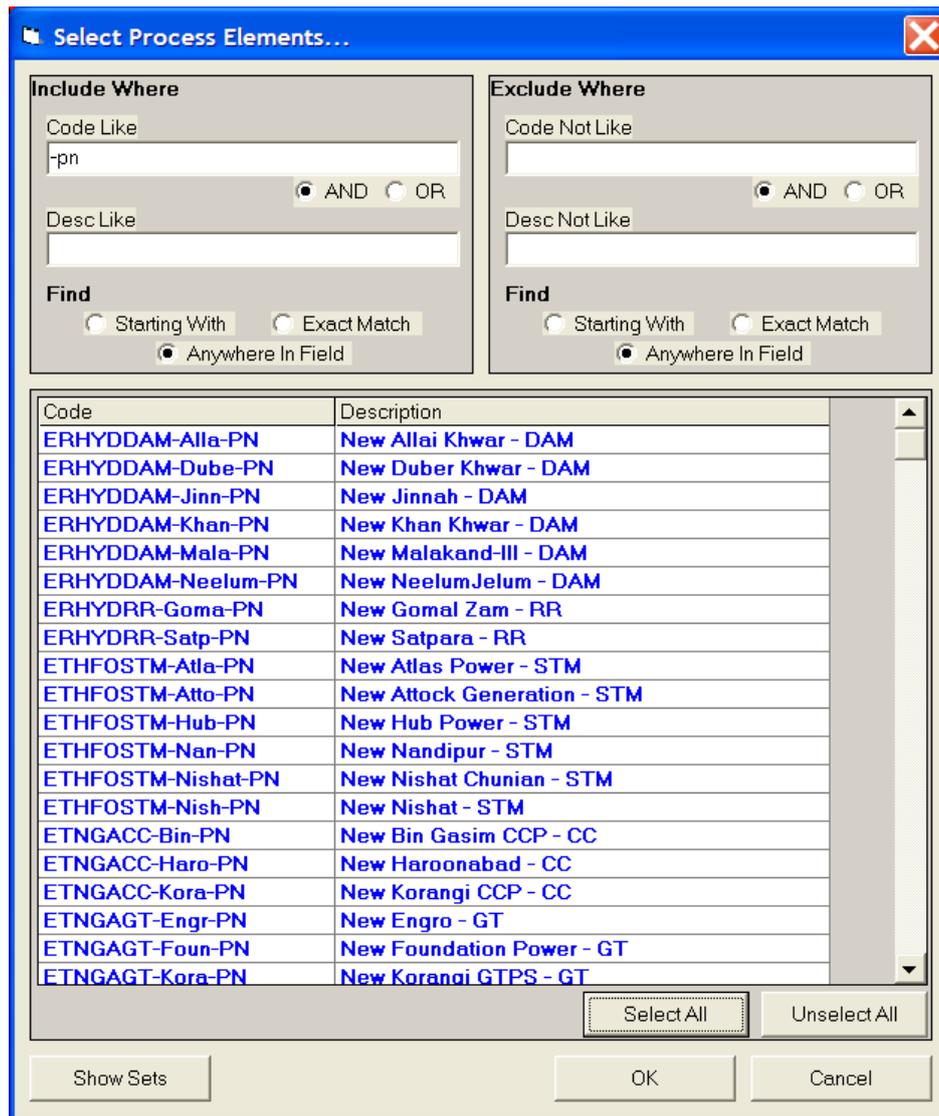


Figure 90: VBE Search Process Window

8.2. RES Diagrams and Data

Another useful facility supported by VBE is the presentation of model results on the RES network diagram. The RES diagram facility is accessed using the View/Reference Energy System [F8] menu command. In order for VBE to display data on the RES it needs to be either qualified down to the granular level, or summed across dimensions. In Figure 91 we can see the power plants linked by their fuel type that produce central station power, showing the electricity generation from each plant in 2015 along with the total fed to the grid. Note that when individual technologies are selected both the flows and all the results data specifically associated with that technology are shown in the window below the RES. One can cascade through the RES by simply clicking on any of the labels, including hitting the "+" when additional flows are hidden from view.

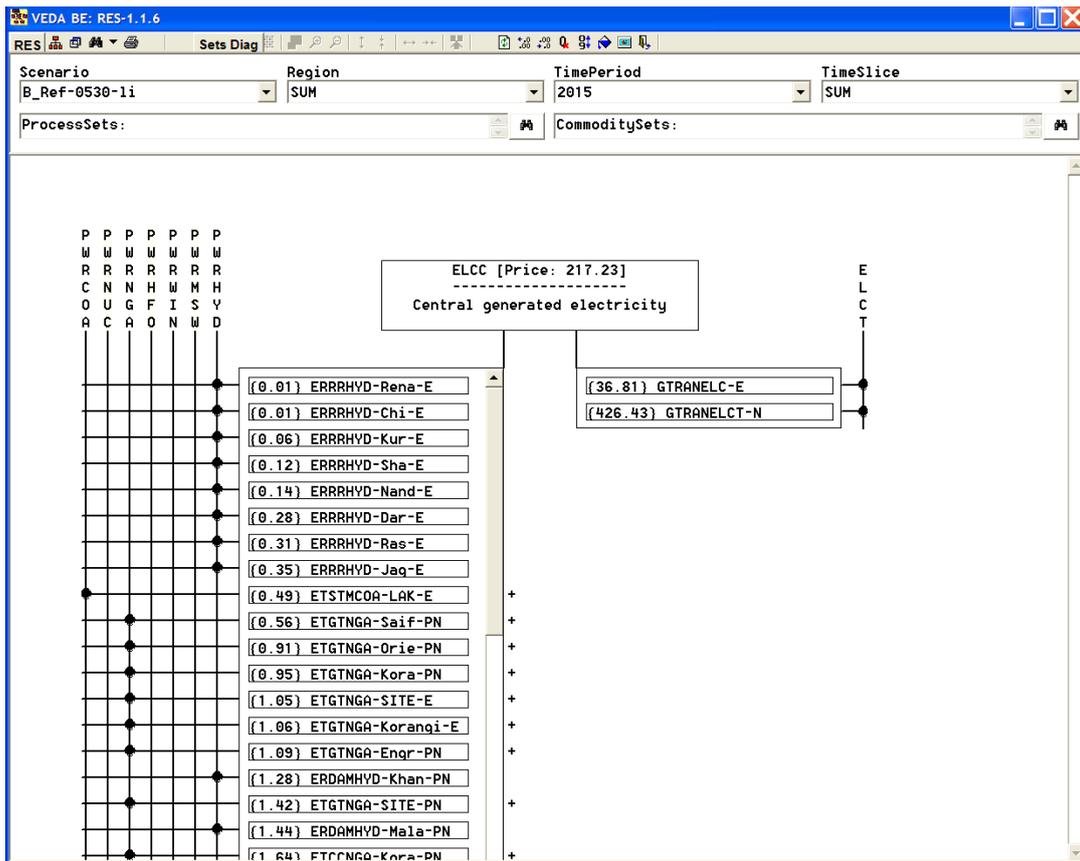


Figure 91: VBE RES Diagram and Data

8.3. RES Component Expansion (ExRES)

An alternative and perhaps less intuitive although more informative way to cascade through the RES to examine model results is via the ExRES (EXpand RES) facility. From the Commodities/Process tabs, or the associated column in any table, via the right-mouse the expansion of the RES from said component can be requested and is presented as a data cube. Clicking again from say a commodity view on a technology will bring that into focus, thus enabling cascading through the RES data.

The view presented by ExRES can either encompass all the data associated with each component, or just the flows in/out of the processes is controlled by toggling  /  for RES-only/details. In Figure 92, the flow out of the power plants and total into the grids can be seen.

Scenario	Commodity	Attribute	Process	2007	2010	2014	2017	2020	2023	2026	20
B-Ref_0621-03g-2	ELCC	VAR_Fin	GTRANELC-E	331.48	363.36	22.09	7.31	22.45	20.81	22.12	
			GTRANELCT-N	~	~	391.97	487.47	599.60	744.99	948.56	1
			Total	331.48	363.36	414.06	494.78	622.05	765.80	970.68	1
		VAR_FOut	ERDAMHYD-Akhor-N	~	~	~	~	~	~	6.88	
			ERDAMHYD-Alla-PN	~	~	~	1.44	2.15	2.15	2.15	
			ERDAMHYD-Bunji-N	~	~	~	~	~	~	~	
			ERDAMHYD-Che-E	4.12	2.01	3.88	3.88	3.88	3.88	3.88	
			ERDAMHYD-Diamer-N	~	~	~	~	~	11.87	31.15	
			ERDAMHYD-Dudhni-N	~	~	~	~	~	~	~	
			ERDAMHYD-Gha-E	24.99	19.60	22.06	22.06	22.06	22.06	22.06	
			ERDAMHYD-Golen-N	~	~	~	1.26	1.89	1.89	1.89	
			ERDAMHYD-Harpo-N	~	~	~	~	~	0.39	0.59	
			ERDAMHYD-Jinn-PN	~	~	~	1.14	1.71	1.71	1.71	
			ERDAMHYD-Kurram-N	~	~	~	0.98	1.48	1.48	1.48	
			ERDAMHYD-Lawi-N	~	~	~	~	~	0.83	1.25	
			ERDAMHYD-Lower-N	~	~	~	~	~	2.23	3.35	
			ERDAMHYD-Mala-PN	~	~	1.44	1.44	1.44	1.44	1.44	
			ERDAMHYD-Mang-E	22.14	18.76	18.76	18.76	18.76	18.76	18.76	

Global Filter Applied For: Scenario - B-Ref_0621-03g-2, P-NoDBH_0420-01, P-NoThar_0419-01

Figure 92: ExRES Data Table from VBE

8.4. Coloring the Cube Display

To assist with viewing of data in VBE, the cube display can be customized via the  pull-down list and coloring window. Above the Back color for the cube data areas is yellow with the Fore color (text) black, the Field Back/Fore colors are black and white, the Header Back/Fore colors are grey and black, and the Total Back/Fore colors are white and blue. So be creative and enjoy, but remember you're going to have to look at them a lot.

8.5. Setting the Export Folder and Layout

VBE will export tables to Excel as “what-you-see-is-what-you-get” layouts. Using the Tools/Options menu command, the Export Options tab, shown in Figure 93 (with recommended options set), the user should establish the folder to which these operations take place, with \VEDA\VEDA_BE\Exports suggested. As part of using the Analytics workbook, in conjunction with Update Excel, we also suggest setting the Export Location to Same Sheet Horizontally. You'll also see on this tab options related to Batch Mode processing operation where you can View the cubes and at the same time automatically export as well. Finally you can also decide whether to see the exported file at the end of a VBE operation. [Note, it is necessary to NOT have spaces in the folder name to use this feature.]

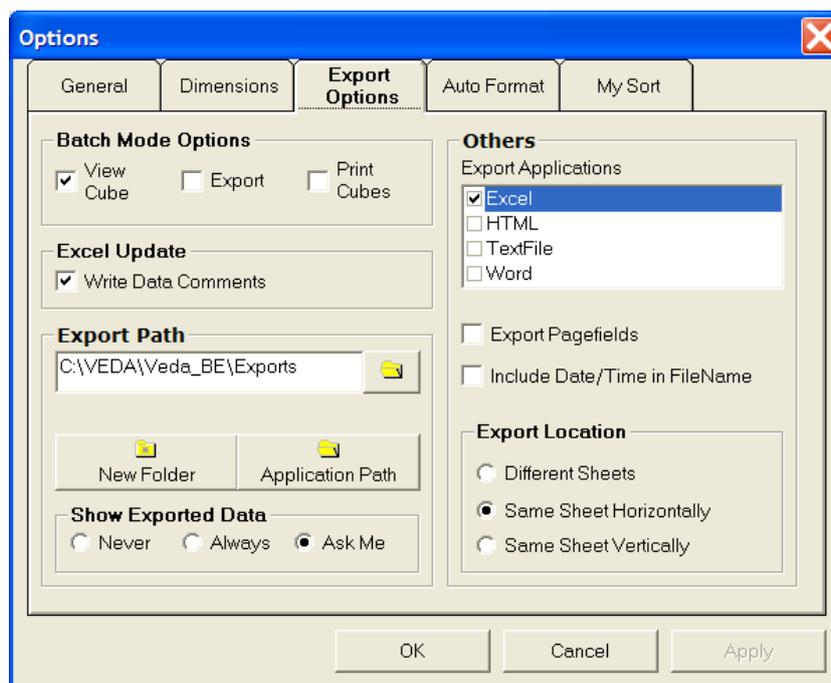


Figure 93: VBE Excel Export Options

8.6. Saving Cubes

The data cubes are the essence of VBE. Each time a table is requested the Cube is dynamically reassembled, almost. If on the Tools/Option/General tab the Save Cube Files is checked, then for each request the resulting cube is written to the Cube Files folder and is available for instant recall – if when the table is requested again there were not changes in circumstances (e.g., same scenarios, sets not changed).

C. Pak-IEM Sets and Tables

As already discussed the VBE Sets and Tables customize the system for a particular model and serve as the core of the analysis support system for that model. While the philosophy and basic operation of VBE were discussed in the previous section, the specific Sets and Tables currently assembled for Pak-IEM are described here.

1. Pak-IEM Sets

The Pak-IEM Sets can be seen in the Export request below for Commodities (Figure 94) and Processes (Figure 95).

Code	Description
BIO	Biomass
COAL	COAL
DEM_AGR	Agriculture
DEM_COM	Commercial
DEM_IND	Industry
DEM_RSD	Residential
DEM_RSDR	Rural
DEM_RSDU	Urban
DEM_TRN	Transport
ELCC	Electricity (Grid-based)
ELCR	Electricity (Remote)
ENV_CO2	CO2
ENV_NOX	NOX
ENV_SO2	SO2
GASASS	Associated Gas
HYDRO	Hydroelectric
NGA	Natural Gas
NUC	Nuclear
OIL	Oil & Products
RNW	Renewables
RNWALL	Renewables (All)
RNWNHYD	Renewables (excl. hydro)
SFUELAGR	Agriculture Fuels
SFUELCOM	Commercial
SFUELIND	Industry
SFUELRSD	Residential
SFUELTRN	Transport

Figure 94: PAK-IEM Commodity Sets

Code	Description	Code	Description
AGR_OTHER	Other	PP_HYDRO	Hydro Plants
AGR_TRACTOR	Tractors	PP_HYDRO(NEW)	PP_HYDRO(NEW)
AGR_WATER	Water pumping	PP_HYDRO(PN)	Planned new Hydro
COM_COOL	Cooling	PP_NUCLE	Nuclear Power Plants
COM_ELCAPP	Elec Appliances	PP_OIL	Oil-fired Power Plants
COM_HEAT	Heating	PP_RENEW(NOHYDRO)	Renewables (non-Hydro)
COM_LIGHT	Lighting	PP_RENTAL	Rental Power
COM_OTHER	Other	REF	Refineries
COM_REFRIG	Refrigeration	RSD_ACCOOLING	AC Cooling
COM_WATHEAT	Water heating	RSD_COOKING	Cooking
COMFUEL	Commercial Fuels	RSD_COOLING	Non-AC Cooling
DMD-AGR	Agriculture	RSD_HEATING	Heating
DMD-COM	Commercial	RSD_LIGHTING	Lighting
DMD-IND	Industry	RSD_MISCELC	Misc electricity
DMD-RSD	Residential	RSD_OTHER	Other
DMD-TRN	Transportation	RSD_RC	Residential Cooling
DMYELC	DMYELC	RSD_REFRIG	Refrigeration
DOM-SUPPLY	Domestic supply	RSD_RH	Residential Heating
DUMIMP	Dummy Imports	RSD_WATERHEAT	Water heating
ELECOA	coal power plants	RSDR_ACCOOLING	Rural AC cooling
ELEWIN	Wind Power	RSDR_COOKING	Rural Cooking
EX_TRN	Existing transport technologies	RSDR_COOLING	Rural Non-AC cooling
GASPIP	GASPIP	RSDR_HEATING	Rural Space heating
GRIDS	Electricity Grids	RSDR_LIGHTING	Rural Lighting
IMP	Imports	RSDR_MISCELC	Rural Misc electricity
IMP_INFR	Large Import Infrastructure Tech	RSDR_OTHER	Rural Other
IND_BRICK	Brick processes	RSDR_REFRIG	Rural Refrigeration
IND_CEMENT	Cement processes	RSDR_WATERHEAT	Rural Water heating
IND_FERTILIZER	Fertilizer processes	RSDU_ACCOOLING	Urban AC Cooling
IND_IRON	I&S processes	RSDU_COOKING	Urban Cooking
IND_OTHER	Other ind processes	RSDU_COOLING	Urban Non-AC cooling
IND_SUGAR	Sugar processes	RSDU_HEATING	Urban Space heating
IND_TEXTILE	Textile processes	RSDU_LIGHTING	Urban Lighting
MIN	Domestic Supply	RSDU_MISCELC	Urban Misc electricity
NEW_TRN	New transport technologies	RSDU_OTHER	Urban Other
PP_MTY	Catch all for missed PPs	RSDU_REFRIG	Urban Refrigeration
PP_COAL	Coal-fired Power Plants	RSDU_WATERHEAT	Urban Water heating
PP_DUAL	Dual-fired Power Plants	SUPPLY-EXP	All energy supply
PP_GAS	Gas-fired Power Plants	T2W	2 wheelers
TBUSES	Buses	T3W	3 wheelers
TCARS	Cars		
THERMAL PLANT	THERMAL PLANT		
TOTHER	Other (Vans, Minivans, Trucks)		
TRD_ENDO	Trade		
TTAXI	Taxi		
XAGR	Agriculture		
XCOM	Commercial		
XELC	Power Sector Fuel Consumption		
XGAS	Natural Gas		
XIND	Industry		
XRSD	Residential		
XTRN	Transport		

Figure 95: PAK-IEM Process Sets

Note that the rule corresponding to each Set definition can be seen by simply hovering the cursor over the set name on the Commodity/Process tab. In addition, the use of a particular Set in Tables can be seen by placing the cursor over the Set on the Commodity/Process tab and using the Used in Tables right-mouse request, VBE will display a message as shown in Figure 96 for PP_COAL.

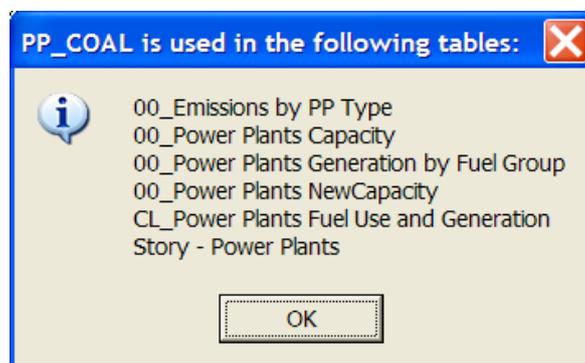


Figure 96: Tables in which Set PP_COAL is Used

For a full understanding of the individual Pak-IEM Sets the analysis should examine each of the rules, and each of the tables in which the Set is used.

2. Pak-IEM Tables

As is discussed in Sections V.C.2.a, b and c, Pak-IEM tables have been prepared to facilitate calibration, Reference scenario assessment, and multi-case comparison, and they have been grouped along these lines into Master Table folders. Almost all the tables are rather straightforward, once they have been built and tested. While each of the groups are briefly described below, the best way for the analyst to become familiar with the Pak-IEM various tables is to open each of them in VBE and review their content and structure.

2.1. Calibration Tables

The tables beginning with “CL_” are the tables used in the *PakIEM_EnergyBalance-2007(Calibration)* workbook. The current list is shown in Figure 97. These are tables that contain only the first year model results and are prepared in energy balance format (rows are sectors, columns are fuels) to facilitate comparison with the 2007 Energy Yearbook data, including checking on the production and consumption of each fuel, and the generation mix.

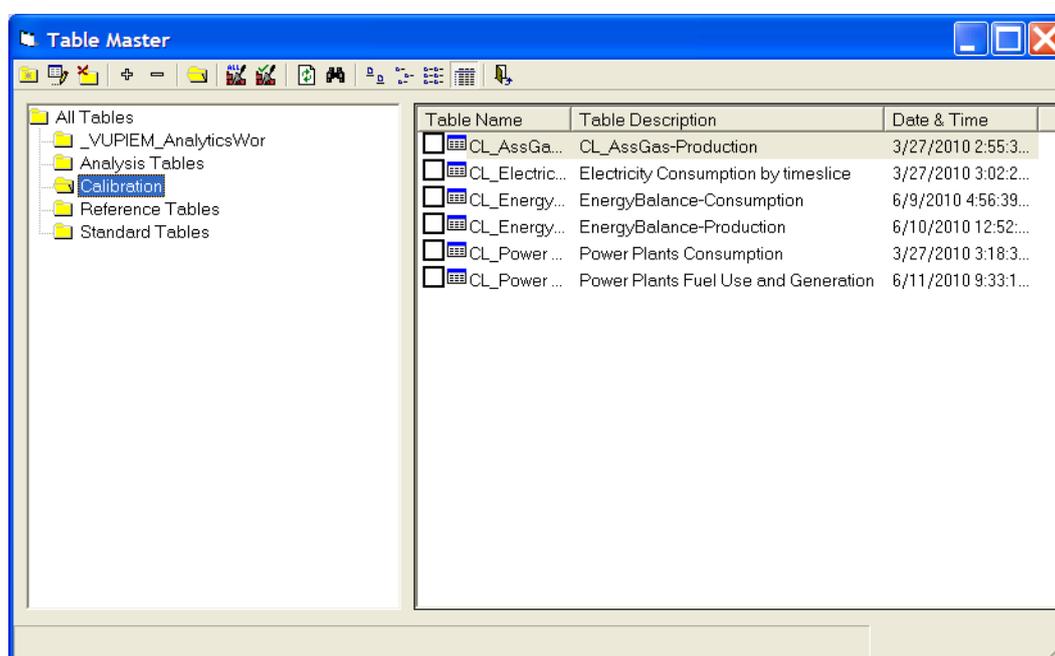


Table Name	Table Description	Date & Time
CL_AssGa...	CL_AssGas-Production	3/27/2010 2:55:3...
CL_Electric...	Electricity Consumption by timeslice	3/27/2010 3:02:2...
CL_Energy...	EnergyBalance-Consumption	6/9/2010 4:56:39...
CL_Energy...	EnergyBalance-Production	6/10/2010 12:52:...
CL_Power ...	Power Plants Consumption	3/27/2010 3:18:3...
CL_Power ...	Power Plants Fuel Use and Generation	6/11/2010 9:33:1...

Figure 97: Pak-IEM Calibration Tables

2.2. Reference Scenario Tables

These tables, which are shown in Figure 98, focus in on resource supply, refinery output, new power plant installations, power plant generation by fuel, and final energy consumption by fuel and sector. They are useful in characterizing the Reference scenario.

Table Name	Table Description	Date & Time
00_Energy...	00_EnergyBalance-FinalEnergybyFuel	1/13/2010 3:36:1...
00_Power ...	00_Power Plants Generation by Fuel ...	1/7/2010 9:21:19...
00_Power ...	00_Power Plants New Installations	3/11/2010 10:34:...
00_Refineri...	00_Refineries Outputs	3/7/2010 11:41:0...
00_Supply	Supply	3/26/2010 8:23:4...
Electricity t...	Electricity to Demand Sectors	3/27/2010 3:19:5...

Figure 98: Pak-IEM Reference Scenario Tables

2.3. Analytics Workbook Tables

Figure 99 lists all the tables currently used in the Pak-IEM Analytics workbook. These tables all begin with ##_ (except for _SysCost) and correspond to the tables that appear on the VEDA_Dump sheets in the PIEM_AnalyticsWorkbook_v## workbook. These tables are automatically updated via the VBE Update Excel facility, as discussed in the next section. They are organized into the following general groups:

- **SysCost** – Total discounted energy system cost (the objective function), and the aggregate annual costs by sector
- **00_** – Aggregate splits of components of the energy system by fuel group or sector, for example resource supply and imports, new power plant builds/installed capacity/generation, final energy consumption, and emissions
- **01_** – Contain demand sector details of energy consumption and technology choice by subsector
- **02_** – Further break downs of the residential sector into urban and rural

Table Name	Table Description	Date & Time
_SysCost	Total Discounted System Cost	7/1/2010 8:04:11...
00_All Cost...	All Costs (by all Sectors)	7/1/2010 8:55:14...
00_Emissio...	00_Emissions by PP Type	12/2/2009 4:11:5...
00_Emissio...	Emissions by Sector	4/2/2010 12:49:3...
00_Energy...	00_EnergyBalance-FinalEnergybyFuel	1/13/2010 3:36:1...
00_Energy...	00_EnergyBalance-FinalEnergybySe...	1/13/2010 3:56:3...
00_Imports-...	Total imports and domestic supply	1/8/2010 5:38:44...
00_Power ...	00_Power Plants Capacity	4/19/2010 3:33:2...
00_Power ...	00_Power Plants Generation by Fuel ...	1/7/2010 9:21:19...
00_Power ...	00_Power Plants New Installations	3/11/2010 10:34:...
00_Refineri...	00_Refineries Outputs	3/7/2010 11:41:0...
00_Supply	Supply	3/26/2010 8:23:4...
01_AGR Fu...	01_AGR Fuels	12/30/2009 1:49:...
01_AGR Su...	01_AGR Subsectors	1/8/2010 9:37:50...
01_COM Fu...	01_COM Fuels	12/30/2009 1:42:...
01_COM S...	01_COM Subsectors	12/30/2009 4:12:...
01_IND Fu...	01_IND fuels	12/30/2009 1:41:...
01_IND Su...	01_IND Subsectors	4/15/2010 8:23:2...
01_RSD Fu...	01_RSD Fuels	12/30/2009 1:34:...
01_RSD Su...	01_RSD Subsectors	1/8/2010 5:20:49...
01_RSDR...	01_RSDR Fuels	1/12/2010 8:39:3...
01_RSDR...	01_RSDR Subsectors	1/12/2010 8:47:4...
01_RSDU...	01_RSDU Fuels	1/12/2010 8:38:0...
01_RSDU...	01_RSDU Subsectors	1/12/2010 8:38:4...
01_TRN Ex...	01_TRN ExNew Techs	12/30/2009 10:2...
01_TRN Fu...	TRN Fuels	12/30/2009 1:38:...
01_TRN R...	01_TRN Road Transport	12/30/2009 1:18:...
02_RSD R...	02_RSD Rural-Urban Demands	1/10/2010 4:04:3...

Figure 99: Pak-IEM Analytics Workbook Tables

REMEMBER, the layouts of all the tables used in VBE Update Excel operations are **NOT** to be changed. Although they may be adjusted while viewing the cubes, the analyst should always exit without saving [Exit (No Save)].

D. Pak-IEM Analytics Workbook

The *PIEM_AnalyticsWorkbook* is a flexible though sophisticated Excel workbook tightly tied to the VBE Update Excel facility discussed in Section IV.B, which permits model run results to be “automatically” updated in the workbook where multiple-case (up to 4 at a time) comparison graphs are automatically refreshed and ready for examining.

Various Visual Basic right-mouse options are available on different sheets to facilitate the management of the Analytics Workbook. The details on how to operate the Workbook to both update with VBE and manipulate the graphs sheets are outlined here and elaborated further in Addendum A.

1. Types of Sheets

The Analytics workbook contains four types of worksheets, each discussed in the following sections.

1.1. Index Sheet

Shown in Figure 100, this sheet lists all the tables in the Workbook, includes a hyperlink to the corresponding worksheet, and provides a short description for each of the sheets. This sheet is maintained manually whenever a new table is added.

1	A	B	C	D	E
2	Analytics VBA v0.00				
3	List of Analysis Tables				
4	VEDA_BE Table Name	Tab Name & Hyperlink	Description	VEDA_Dump Sheet	
5	_SysCost	Scenarios	Total discounted system cost (TIMES Objective Function)	SUP	
6	00_All Costs (by all Sectors)	All_Costs(by Sector)	Costs corresponding to different sectors of the energy system	SUP	
7	00_Emissions by PP Type	Emission_PP (by Type)	Emissions from different types of power plants	ELC	
8	00_EnergyBalance-FinalEnergybyFuel	EB_FinalEnergy (by Fuel)	Final energy consumed by fuel	SUP	
9	00_EnergyBalance-FinalEnergybySector	EB_FinalEnergy (by Sector)	Final energy consumed in each of the sectors	SUP	
10	00_EnergyBalance-FinalEnergybySector	Energy Intensity	Energy intensity of the system in various scenarios	SUP	
11	00_Imports-DomSupply	Imports_Supply	Share of imported energy relative to the total energy consumed	SUP	
12	00_Power Plants Generation by Fuel Group	Power Generation (by Fuel)	Power plant output by fuel type	ELC	
13	00_Power Plants NewCapacity	Power Sector Investment	New capacity added in each time period by generation type	ELC	
14	00_Refineries Outputs	Refinery Output	Breakdown of refinery output by fuel type	SUP	
15	00_Supply	EB_Supply	Primary energy supply by fuel source	SUP	
16	01_AGR Fuels	AGR Fuels	Fuel mix consumed in the agriculture sector	DMD	
17	01_AGR Subsectors	AGR Sectors	Energy consumed by different agricultural subsectors	DMD	
18	01_COM Fuels	COM Fuels	Fuel mix consumed in the commercial sector	DMD	
19	01_COM Subsectors	COM Sectors	Energy consumed by different commercial subsectors	DMD	
20	01_IND Fuels	IND Fuels	Fuel mix consumed in the industrial sector	DMD	
21	01_IND Subsectors	IND Sectors	Energy consumed in different industrial processes. This does not include the energy generated from the CHP and ther auto generation plants.	DMD	
22	01_RSD Fuels	RSD Fuels	Fuel mix consumed in the residential sector	DMD	
23	01_RSD Subsectors	RSD Sectors	Energy consumed by different residential subsectors	DMD	
24	01_RSDR Fuels	RSDR Fuels	Fuel mix consumed in the rural residential sector	DMD	
25	01_RSDR Subsectors	RSDR Sectors	Energy consumed by different residential subsectors in rural households	DMD	
26	01_RSDU Fuels	RSDU Fuels	Fuel mix consumed in the urban residential sector	DMD	
27	01_RSDU Subsectors	RSDU Sectors	Energy consumed by different residential subsectors in urban households	DMD	
28	01_TRN ExNew Techs	TRN TechGrps	Contribution of new and old transportation technologies in meeting the total demand	DMD	
29	01_TRN Fuels	TRN Fuels	Fuel mix consumed by road transport vehicles	DMD	
30	01_TRN Road Transport	TRN RoadVehicles	Energy consumed by different types of road transport vehicles	DMD	

Figure 100: Pak-IEM Analytics Workbook – Index Sheet

1.2. VEDA_DUMP_<***> Sheets

As shown in Figure 101, these sheets contain the raw VBE exported cube tables that are updated by the Update Excel facility. These sheets only need to be reviewed if questions arise in the Update Excel logs, or if a new table is to be added.

1	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
2	VEDA-BE Update XLS Dump Tables - Power																				
3																					
4																					
5	Table Name: 00_Power Plants Generation by Fuel Group										Table Name: 00_Power Plants NewCapacity										
6	Active Unit: PJ	Block #	9								Active Unit: GW										
7	Scenario	ProcessSetDesc/Per	2007	2010	2014	2017	2020	2023	2026	2030	Scenario	ProcessSetDesc/Period	2010	2014	2017	2020	2023	2026	2030		
8	B-Ref_0705-01	Coal-fired Power Pl	0.490042	0.490093	0.490093	0.490093	16.66652	63.66885	64.70802	279.1528	B-Ref_0705-01	Coal-fired Power Plants	0	0	0	0.603472	1.753452	0.05705			
9	B-Ref_0705-01	Diesel generators	0.487365	0	0	0	0	0	0	0	B-Ref_0705-01	Diesel generators	0	0	0	0	0	0	0	0	0
10	B-Ref_0705-01	Dual-fired Power Pl	100.3616	100.3616	99.10314	94.32824	94.32824	94.32824	66.42412	24.2856	B-Ref_0705-01	Dual-fired Power Plants	0	0	0	0	0	0	0	0	0
11	B-Ref_0705-01	Gas-fired Power Pla	46.23277	68.13148	74.89262	91.93626	87.72026	22.194	22.194	22.194	B-Ref_0705-01	Gas-fired Power Plants	1.914	0.56	0	0	0	0	0	0	0
12	B-Ref_0705-01	Hydro Plants	114.6008	42.88924	111.3557	128.9778	164.4624	195.5993	224.5245	266.7998	B-Ref_0705-01	Hydro Plants	0.423	1.485	1.5	1.5	1.5	2			
13	B-Ref_0705-01	Nuclear Power Plan	8.207526	8.281511	16.79292	16.79292	16.79292	83.41578	179.2064	287.7991	B-Ref_0705-01	Nuclear Power Plants	0.325	0	2.34733	2.7	2.7	3.6			
14	B-Ref_0705-01	Oil-fired Power Plar	61.7076	88.37917	68.85576	61.7076	61.7076	56.8656	42.8652	6.388189	B-Ref_0705-01	Oil-fired Power Plants	2.019	0	0	0	0	0	0	0	0
15	B-Ref_0705-01	Renewables (non-H	0.000735	0.001646	0.000957	14.06264	21.26377	22.99611	24.69098	27.23552	B-Ref_0705-01	Renewables (non-Hydro)	0	0.76784	0.03	0.10789	0.064618	0.100581	0	0	0
16	B-Ref_0705-01	Total	332.0884	308.5347	371.4912	408.2956	462.9417	539.0679	624.6132	913.82	B-Ref_0705-01	Total	4.681	2.81284	3.87733	4.911362	6.01807	5.75731	10		
17	B-RefSP_0705-01	Coal-fired Power Pl	0.490042	0.490093	0.490093	0.490093	14.53608	74.53608	85.49946	334.6731	B-RefSP_0705-01	Coal-fired Power Plants	0	0	0	2.792333	0	0	1.722862		
18	B-RefSP_0705-01	Diesel generators	0.487365	0	0	0	0	0	0	0	B-RefSP_0705-01	Diesel generators	0	0	0	0	0	0	0	0	0
19	B-RefSP_0705-01	Dual-fired Power Pl	100.3616	100.3616	99.10314	94.32824	94.32824	94.32824	66.42412	47.95394	B-RefSP_0705-01	Dual-fired Power Plants	0	0	0	0	0	0	0	0.573105	
20	B-RefSP_0705-01	Gas-fired Power Pla	46.23277	68.13148	58.58654	84.87083	94.72559	22.194	22.194	34.04868	B-RefSP_0705-01	Gas-fired Power Plants	1.914	0.56	0	0	0	0	0	0	0
21	B-RefSP_0705-01	Hydro Plants	114.6008	42.88924	111.3557	128.9778	164.4624	195.5993	224.5245	266.7998	B-RefSP_0705-01	Hydro Plants	0.423	1.485	1.5	1.5	1.5	2			
22	B-RefSP_0705-01	Nuclear Power Plan	8.207526	8.281511	16.79292	16.79292	16.79292	83.41578	179.2064	287.7991	B-RefSP_0705-01	Nuclear Power Plants	0.325	0	0	2.34733	2.7	2.7	3.6		
23	B-RefSP_0705-01	Oil-fired Power Plar	61.7076	88.37917	68.85576	61.7076	61.7076	56.8656	42.8652	14.44435	B-RefSP_0705-01	Oil-fired Power Plants	2.019	0	0	0	0	0	0	0	0
24	B-RefSP_0705-01	Renewables (non-H	0.000735	0.001646	0.000957	14.06264	21.26377	22.99611	24.69098	27.23552	B-RefSP_0705-01	Renewables (non-Hydro)	0.621745	0.146095	0.03	0.10789	0.064618	0.100581	0	0	0
25	B-RefSP_0705-01	Total	332.0884	308.5351	371.8514	406.7856	467.8166	539.7999	633.23	1,002.75	B-RefSP_0705-01	Total	5.302783	2.191093	3.51872	7.070222	4.264513	7.996649	18		
26	P_DL_0705-v01	Coal-fired Power Pl	0.490042	0.490093	0.490093	0.490093	49.09502	65.04622	64.55612	233.1017	P_DL_0705-v01	Coal-fired Power Plants	0	0	0	0	1.813238	0.59507	0	0	0
27	P_DL_0705-v01	Diesel generators	0.487365	0	0	0	0	0	0	0	P_DL_0705-v01	Diesel generators	0	0	0	0	0	0	0	0	0
28	P_DL_0705-v01	Dual-fired Power Pl	100.3616	100.3616	99.10314	94.32824	94.32824	94.32824	66.42412	32.51502	P_DL_0705-v01	Dual-fired Power Plants	0	0	0	0	0	0	0	0	3.578
29	P_DL_0705-v01	Gas-fired Power Pla	46.23277	68.13148	75.73049	87.89519	94.72559	22.194	22.194	22.53947	P_DL_0705-v01	Gas-fired Power Plants	1.914	0.56	0	0	0	0	0	0	0
30	P_DL_0705-v01	Hydro Plants	114.6008	97.12151	105.2881	121.478	156.2565	187.3934	216.3186	258.5939	P_DL_0705-v01	Hydro Plants	0.081	1.366	1.5	1.5	1.5	2			
31	P_DL_0705-v01	Nuclear Power Plan	8.207526	8.281511	16.79292	16.79292	16.79292	83.41578	179.2064	199.3051	P_DL_0705-v01	Nuclear Power Plants	0.325	0	0	0	2.34733	2.7	3.6		
32	P_DL_0705-v01	Oil-fired Power Plar	61.7076	88.37917	68.85576	61.7076	61.7076	56.8656	42.8652	9.421062	P_DL_0705-v01	Oil-fired Power Plants	2.019	0	0	0	0	0	0	0	0
33	P_DL_0705-v01	Renewables (non-H	0.000735	0.001646	0.000957	14.06264	21.26377	22.99611	24.69098	27.15907	P_DL_0705-v01	Renewables (non-Hydro)	0	0.76784	0.03	0.10789	0.064618	0.100581	0	0	0
34	P_DL_0705-v01	Total	332.0884	363.358	366.2414	396.7547	434.1697	465.6165	527.7915	782.64	P_DL_0705-v01	Total	4.339	2.69384	1.53	5.351598	4.859687	5.700581	13.61		
35	P_DM_0705-v01	Coal-fired Power Pl	0.490042	0.490093	0.490093	0.490093	62.33819	62.33819	61.8681	262.3282	P_DM_0705-v01	Coal-fired Power Plants	0	0	0	0	2.308209	0	0	0	0
36	P_DM_0705-v01	Diesel generators	0.487365	0	0	0	0	0	0	0	P_DM_0705-v01	Diesel generators	0	0	0	0	0	0	0	0	0
37	P_DM_0705-v01	Dual-fired Power Pl	100.3616	100.3616	99.10314	94.32824	94.32824	94.32824	66.42412	42.8616	P_DM_0705-v01	Dual-fired Power Plants	0	0	0	0	0	0	0	0	0
38	P_DM_0705-v01	Gas-fired Power Pla	46.23277	68.13148	79.35883	91.11969	94.72559	22.194	22.194	35.96193	P_DM_0705-v01	Gas-fired Power Plants	1.914	0.56	0	0	0	0	0	0	0

Figure 101: Pak-IEM Analytics Workbook – VEDA_Dump Sheet

1.3. Scenarios Sheet

As shown in Figure 102, this sheet contains the list and brief descriptions of all the scenarios included in the workbook, along with the system cost for each individual scenario. In addition, this sheet is where the analyst can select 4 particular scenarios (out of the total list) for display in the Graphing sheets.

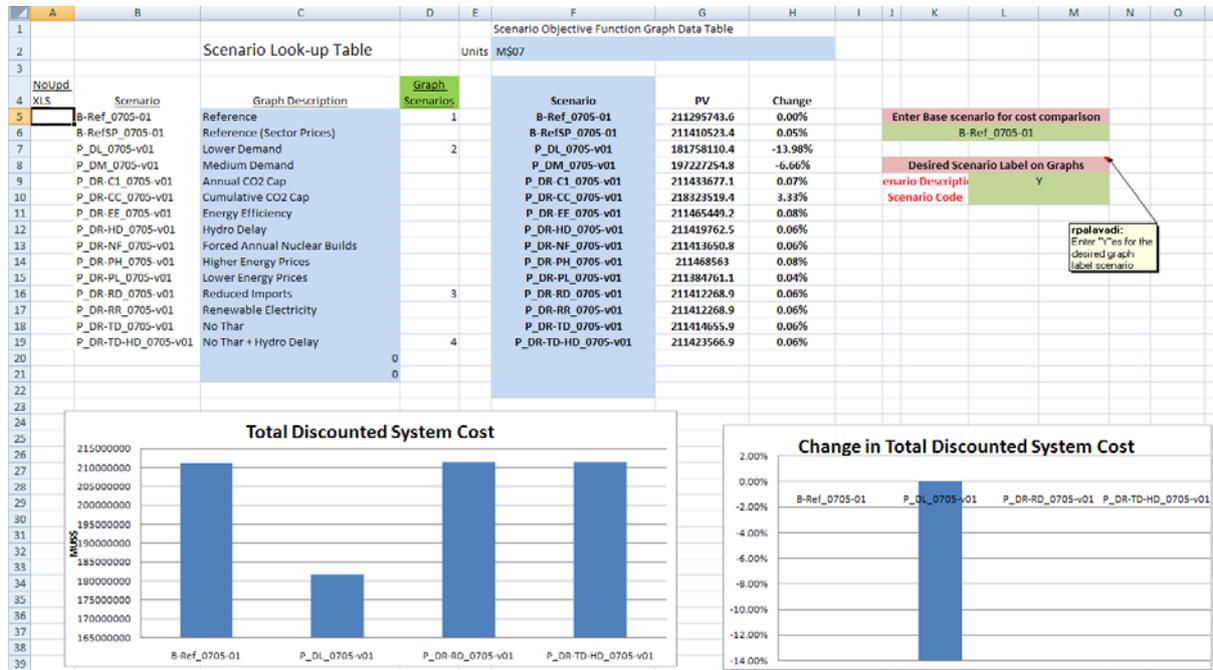


Figure 102: Pak-IEM Analytics Workbook – Scenario Sheet

1.4. Graphing Sheets

As shown in Figure 103, these sheets are where the results comparison tables and graphs (first scenario details, 4-case comparison, and 3-case difference from first) are managed directly. [Note that on the Graph sheets in the comparison data area, the graphed scenario data is reported and a CheckSum done to ensure that the Total in the VEDA_Dump table matches what has been assembled in the graph data area.]

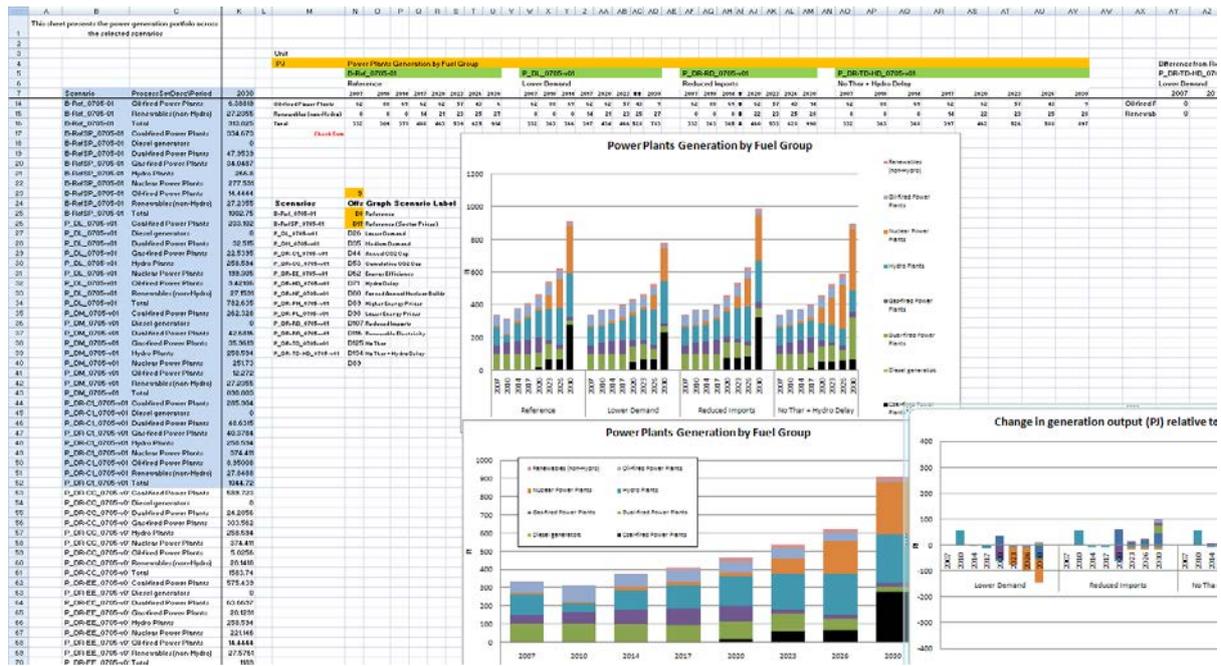


Figure 103: Pak-IEM Analytics Workbook – Index Sheet

The functionality and core operations most often performed to manage the Workbook are introduced below, and elaborated further in Addendum A.

2. Managing Scenarios

It is essential to synchronize the names of the Scenarios currently active in the Workbook with those current “seen” by VBE. This is mainly accomplished using the **Rename, Add, and Delete** scenario right-mouse option, from the cell in **Column-B** that has the scenario name, to perform the desired operation. These operations result in all the VEDA_Dump and Graph sheet tables to be updated appropriately.

3. VBE Update Excel Functions and Logs

Update Excel is a very demanding task that can take quite a bit of time. In addition, the current Update Excel function deletes any data not specified in VBE for the update. This combination of functionality has resulted in additional facilities being added to the Analytics workbook to allow only selected scenarios (those which have been rerun in VFE) to be processed by the Update Excel facility so that existing information is not lost and the update operation performs more quickly.

The process is managed by placing a “*” in Column-A next to all Scenarios that **DO NOT NEED TO BE UPDATED** at this time (right-mouse “All/Remove *” can be handy), and via the right-mouse from [A4] requesting “Prepare for Update.” [Below only the Low/Medium demand scenario will be updated.] This both comments out all the “*” Scenarios on all VEDA_Dump sheets (so that VBE Update Excel does not “see” them) and sets the Excel Options\Formulas – Manual to speed the actual update operation. [Excel Options\Formulas – Manual should be done manually if not using the Prepare option.]

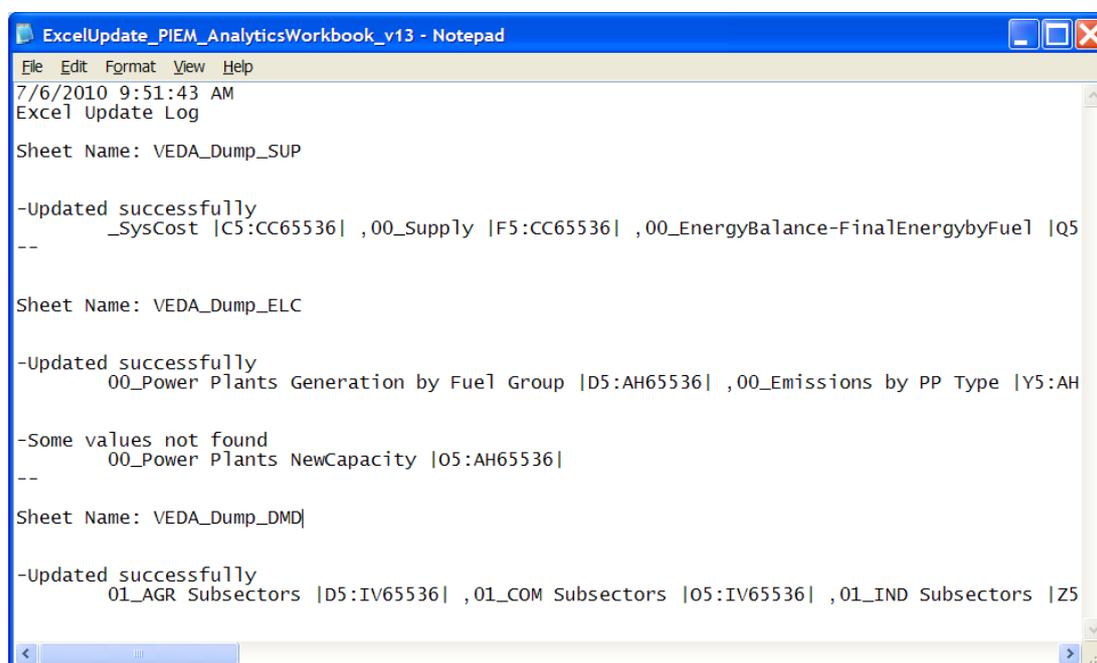
The various options available on the Scenario sheet for managing the Workbook current Update Excel and Graph scenarios are shown via the right-mouse and described in more detail in Addendum A.

Once the desired scenarios are set up in the Workbook the Update Excel process can proceed by indicating whether All or Selected tables are to be updated (and if the latter later which ones) and identifying the *PIEM_AnalyticsWorkbook* to be updated *{make sure it is closed, and don't open a new Excel workbook during the Update Excel operation.}* While VBE is performing the Update Excel the various tables being constructed and updated are echoed at the bottom of the form.

At the end of the Update Excel procedure VBE will let you know if any tables or cells were not aligned between VBE and its cube layout/Global filter settings and what is active in the Workbook. One log reports on any cells not updated (which are shaded red on the VEDA_Dump sheets) or missing (e.g., if the Global Filter includes a Scenario that is not found (or seen) in the Workbook). The Analysts should regularly check these Logs to ensure that the Update Excel performs as expected. The Update log, shown in Figure 104, indicates that on each sheet most tables were updated without a problem, except for *00_Power Plants NewCapacity* which has a row for Diesel plants for which no new builds are undertaken.

4. Controlling Scenarios Graphed

The scenarios involved in the three figures of each graph sheet can be controlled for all sheets via the Scenario sheet, with the Refresh Graph option after providing the sequencing index in Col-D for each other scenario to be graphed. Alternatively the scenario shown on any particular graph sheet may be set for that sheet (till the next Scenario sheet Refresh Graph is done) via a right-mouse click anywhere on the sheet, which opens the selection box shown in Figure 105. The analyst can then move the scenarios in/out of the Graph list, order them as desired, and click Refresh Graph.



```

ExcelUpdate_PIEM_AnalyticsWorkbook_v13 - Notepad
File Edit Format View Help
7/6/2010 9:51:43 AM
Excel Update Log

Sheet Name: VEDA_Dump_SUP

-Updated successfully
  _SysCost |C5:CC65536| ,00_Supply |F5:CC65536| ,00_EnergyBalance-FinalEnergybyFuel |Q5
--

Sheet Name: VEDA_Dump_ELC

-Updated successfully
  00_Power Plants Generation by Fuel Group |D5:AH65536| ,00_Emissions by PP Type |Y5:AH

-Some values not found
  00_Power Plants NewCapacity |O5:AH65536|
--

Sheet Name: VEDA_Dump_DMD

-Updated successfully
  01_AGR Subsectors |D5:IV65536| ,01_COM Subsectors |O5:IV65536| ,01_IND Subsectors |Z5

```

Figure 104: VBE Log File

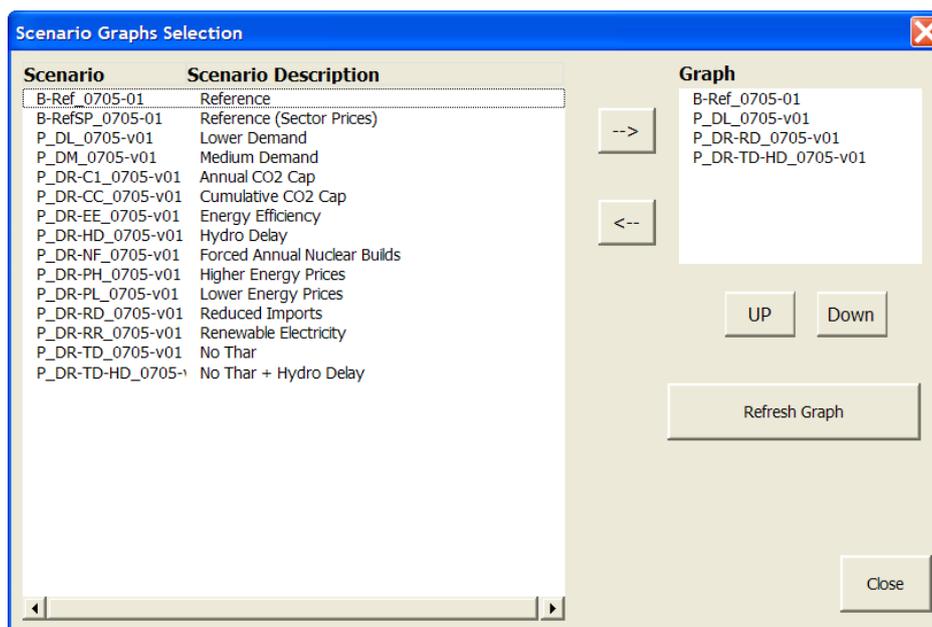


Figure 105: Refresh Graph Selection Box

5. Other Analytics Workbook Features

The user should refer to Addendum A for more advanced features, such as Adding New VEDA_Dump Tables and Graph Sheets, and adjusting Model run periods.

Addendum A: Using the Pak-IEM Analytics Workbook

The IRG-Analytics workbook is an interactive Excel workbook that manages and presents results from the Pak-IEM TIMES model runs. The workbook is linked to a VBE database and facilitates managing and updating of model run results. It also allows the analyst to select and examine a subset of model runs for analysis of model behavior and for presentation of model results to decision-makers.

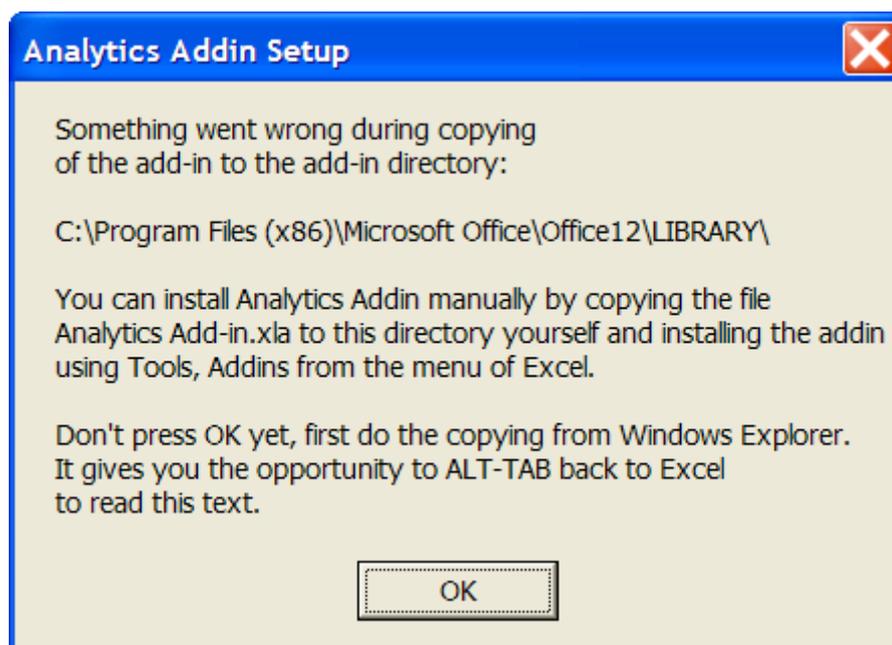
The Pak-IEM Analytics workbook contains results tables and charts covering almost all aspects of the energy system using multi-case comparison graphs in three formats and comparing up to four scenarios at a time. One chart presents the results of the first scenario selected; the second compares the results of the four scenarios in the order selected by the analyst, and the third displays the differences of the second, third, and fourth scenarios to the first. The tables and graphs included in the Pak-IEM workbook cover primary and final energy consumption, power plant generation, installed capacity, and new builds along with the associated investment required, fuel consumption in individual demand sectors, CO₂ emissions, and sector-specific details.

A collection of Visual Basic functions available in the Analytics workbook enables:

- Scenarios to be added, deleted or renamed
- The workbook to be readied for updating all or only selective scenarios using the VEDA-BE (VBE) Update Excel function
- Scenarios to be selected for display on the various results graphs to facilitate examining and digesting the model results
- New tables and graphing sheets to be added to the workbook

A. Introducing the IRG-Analytics VBE_UpdateXLS Add-in

The Analytics Excel Visual Basic Add-in that activates various interactive features of the workbook needs to be installed on the system before using this workbook. The Add-in set up package in the form of a .zip file is distributed to the Planning Team. The user then needs to unzip this package in any chosen location (\VEDA\VBEDA_BE\IRG_Addin suggested). The Add-in can be installed by opening the file Setup_Analytics_Addin and clicking the “Setup Analytics Addin” button as shown in Figure 106. The “Remove Analytics Addin” button uninstalls the add-in from the system. A second file named VD is also sent along with the Setup_Analytics_Addin file as a part of the setup package. This contains the actual code for the Add-in and does not need to be accessed by the users.



Ran the old Setup to do Remove. Closed it and upRAREd the new one. Ran Setup to Install and get this. When I go to ProgramFiles the Add-in is still there and cant deleted/replaced. So closed Excel and tried same procedure again - all OK. Will add to the Analytics Users' Guide.

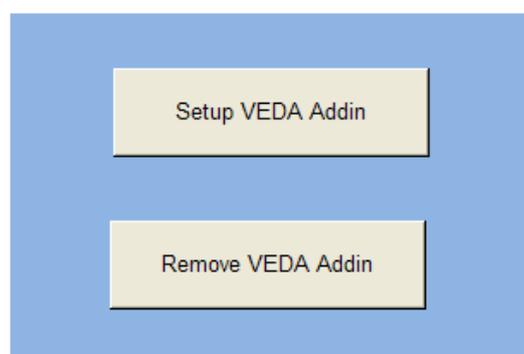


Figure 106: Setup_Analytics_Addin Installation

B. Types of Worksheets

The Analytics workbook consists of five different types of sheets discussed here. At the end of this section the list of the right-mouse invoked *operations* that can be performed on each sheet to manage the workbook is provided.

1. Index

The Index sheet, shown in Figure 107, lists all the tables in the workbook and includes a hyperlink to the corresponding worksheet and a short description for each of the sheets. It also identifies the VEDA_Dump Sheet on which the original VBE Update Excel table can be found.

VEDA_BE Table Name	Tab Name & Hyperlink	Description	VEDA_Dump Sheet
_SysCost	Scenarios	Total discounted system cost (TIMES Objective Function)	SUP
00_All Costs (by all Sectors)	All_Costs(by Sector)	Costs corresponding to different sectors of the energy system	SUP
00_Emissions by PP Type	Emission_PP (by Type)	Emissions from different types of power plants	ELC
00_EnergyBalance-FinalEnergybyFuel	EB_FinalEnergy (by Fuel)	Final energy consumed by fuel	SUP
00_EnergyBalance-FinalEnergybySector	EB_Final Energy (by Sector)	Final energy consumed in each of the sectors	SUP
00_EnergyBalance-FinalEnergybySector	Energy Intensity	Energy intensity of the system in various scenarios	SUP
00_Imports-DomSupply	Imports_Supply	Share of imported energy relative to the total energy consumed	SUP
00_Power Plants Generation by Fuel Group	Power Generation (by Fuel)	Power plant output by fuel type	ELC
00_Power Plants NewCapacity	Power Sector Investment	New capacity added in each time period by generation type	ELC
00_Refineries Outputs	Refinery Output	Breakdown of refinery output by fuel type	SUP
00_Supply	EB_Supply	Primary energy supply by fuel source	SUP
01_AGR Fuels	AGR Fuels	Fuel mix consumed in the agriculture sector	DMD
01_AGR Subsectors	AGR Sectors	Energy consumed by different agricultural subsectors	DMD
01_COM Fuels	COM Fuels	Fuel mix consumed in the commercial sector	DMD
01_COM Subsectors	COM Sectors	Energy consumed by different commercial subsectors	DMD
01_IND Fuels	IND Fuels	Fuel mix consumed in the industrial sector	DMD
01_IND Subsectors	IND Sectors	Energy consumed in different industrial processes. This does not include the energy generated from the CHP and ther auto generation plants.	DMD
01_RSD Fuels	RSD Fuels	Fuel mix consumed in the residential sector	DMD
01_RSD Subsectors	RSD Sectors	Energy consumed by different residential subsectors	DMD
01_RSDR Fuels	RSDR Fuels	Fuel mix consumed in the rural residential sector	DMD
01_RSDR Subsectors	RSDR Sectors	Energy consumed by different residential subsectors in rural households	DMD
01_RSDU Fuels	RSDU Fuels	Fuel mix consumed in the urban residential sector	DMD
01_RSDU Subsectors	RSDU Sectors	Energy consumed by different residential subsectors in urban households	DMD
01_TRN ExNew Techs	TRN TechGrps	Contribution of new and old transportation technologies in meeting the total demand	DMD
01_TRN Fuels	TRN Fuels	Fuel mix consumed by road transport vehicles	DMD
01_TRN Road Transport	TRN RoadVehicles	Energy consumed by different types of road transport vehicles	DMD

Figure 107: List of Pak-IEM Analytics Workbook Tables

2. Scenarios

This sheet, shown in Figure 108, provides the list of all scenarios currently being managed in the workbook along with a brief description for each scenario. Each scenario represents the results of a particular model run, and the name in the Analytics workbook must exactly match the scenario name and description in VBE. The Analytics workbook is designed to allow the user to selectively view up to four (4) scenarios at a time on the Graphing sheets. This choice of scenarios can be made from the Scenario sheet (see Section C), where the scenarios selected will be applied to all the Graphing sheets in the workbook.

This sheet also allows the user to choose either the scenario name or description for labeling graphs in the workbook using a selection list.

Scenario	Description
NoUpd	
B-Ref_0830	Reference
B-Ref_0830_RFNRY	Refinery 1
B-Ref_0830_RFNRY2	Refinery 2
P_DH_0715-01	High demand

Figure 108: Scenarios Worksheet

3. VEDA_Dump Sheets

These sheets are linked directly to the model post-processor, VBE, which permits the manipulation of run results to construct the various tables presented in the Analytics workbook. The Pak-IEM workbook has three of these sheets containing raw output tables from VBE organized according to Resource Supply (VEDA_DUMP_SUP), Power sector (VEDA_DUMP_ELC), and Demand sectors (VEDA_DUMP_DMD). See Figure 109 for an example. **Users should not alter data on these sheets**, although they may be perused by the interested analyst. See Section F for a discussion of how to add a new VBE table to the VEDA_Dump sheet, and create an associated Graphing Sheet.

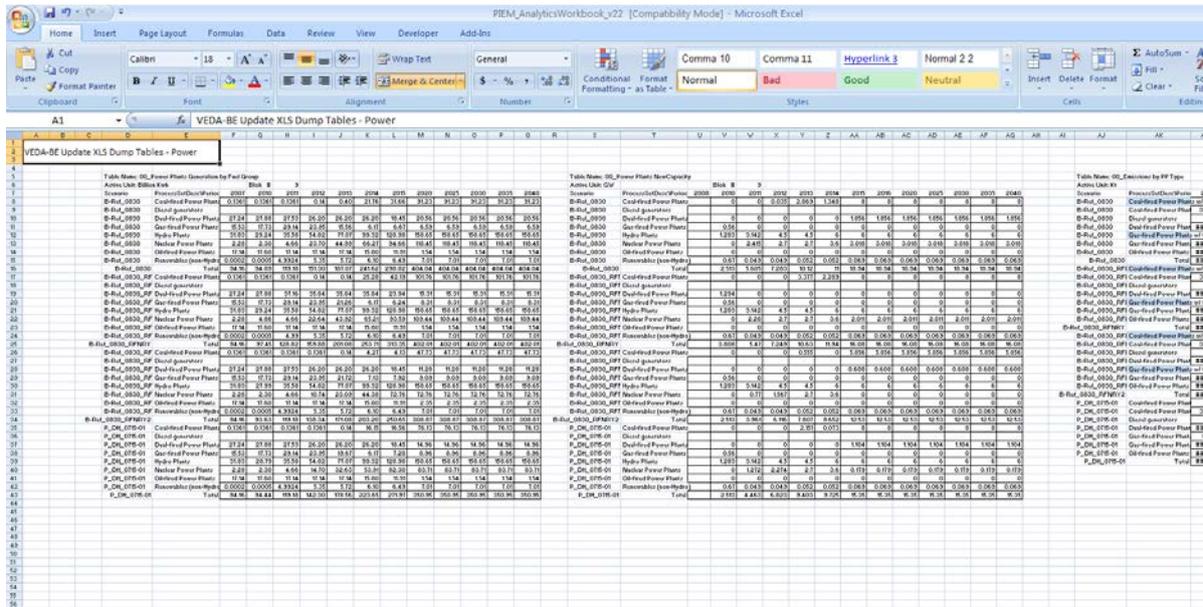


Figure 109: Power Sector VEDA_DUMP Sheet

4. Graphing Sheets

These sheets present the detailed model results in tables and graphs, four scenarios at a time. These sheets constitute the primary workspace for analyzing the Pak-IEM model results, and each generally presents four stacked bar charts containing results for the four scenarios organized as follows and as shown in Figure 110:

- Level of the 4 selected scenarios – side-by-side
- Level of the first (typically reference) scenario only
- Difference of scenarios 2, 3, and 4 compared to scenario 1
- Percentage difference from scenario 1

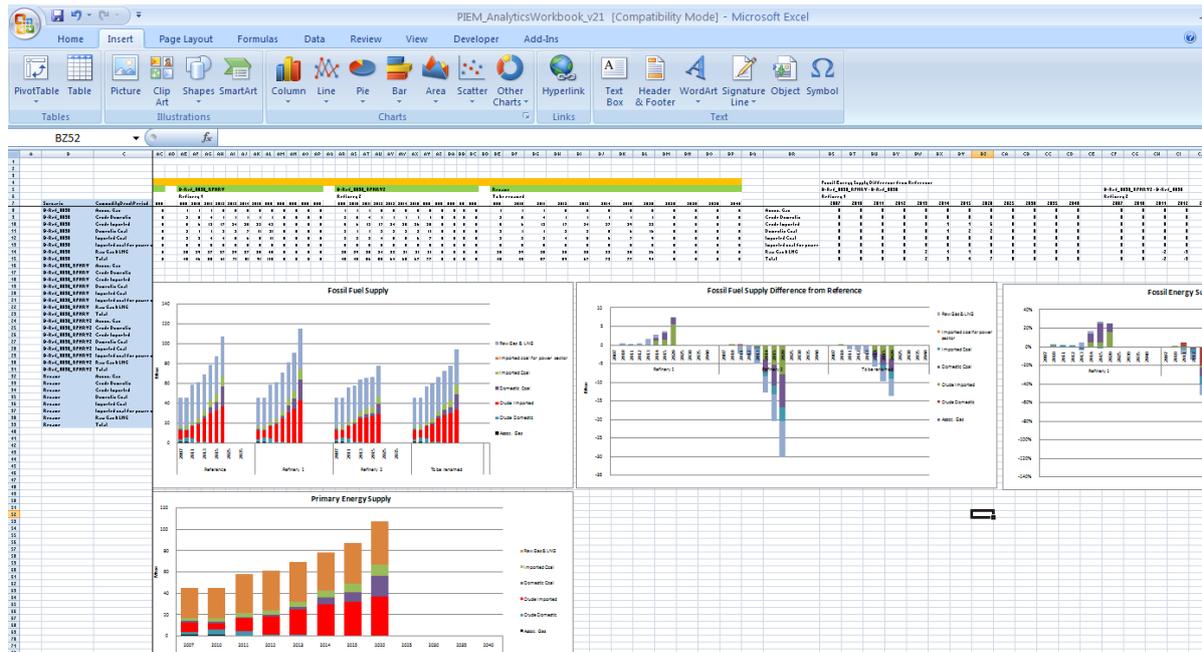


Figure 110: Typical Graph Worksheet

Each Graphing sheet is directly tied to a particular table in the VEDA_Dump sheets, and the data from the VEDA_Dump sheet is brought into the graphing sheets in the blue area on the left. As discussed in Section F, the link is established by means of setting reference link in cell B7 to reference the corresponding table name cell on the corresponding VEDA_Dump sheet and invoking the *SquareTable* function.

The rest of the sheet contains the indexes and graphing tables created using Excel formulas to create the stacked bar charts corresponding to four chosen scenarios. Graph data corresponding to these scenarios begins in row 8 / column Q, with several calculation blocks preparing the data for display. Generally, the formulas in these cells are generated by the Analytics Add-in code and the analyst should not make any changes here.

5. Metrics Sheet

This sheet, shown in Figure 111, provides a high-level summary of changes in key model results with respect to the Reference scenario for the currently selected scenarios. The table currently presents six metrics for the energy system that include: changes in total discounted system cost, primary fuel supply, electricity and energy imports, power plant new builds, final energy consumption, fuel imports, and CO₂ emissions. The tables/ graphing sheets from which these metrics are derived are listed on the metrics sheet.

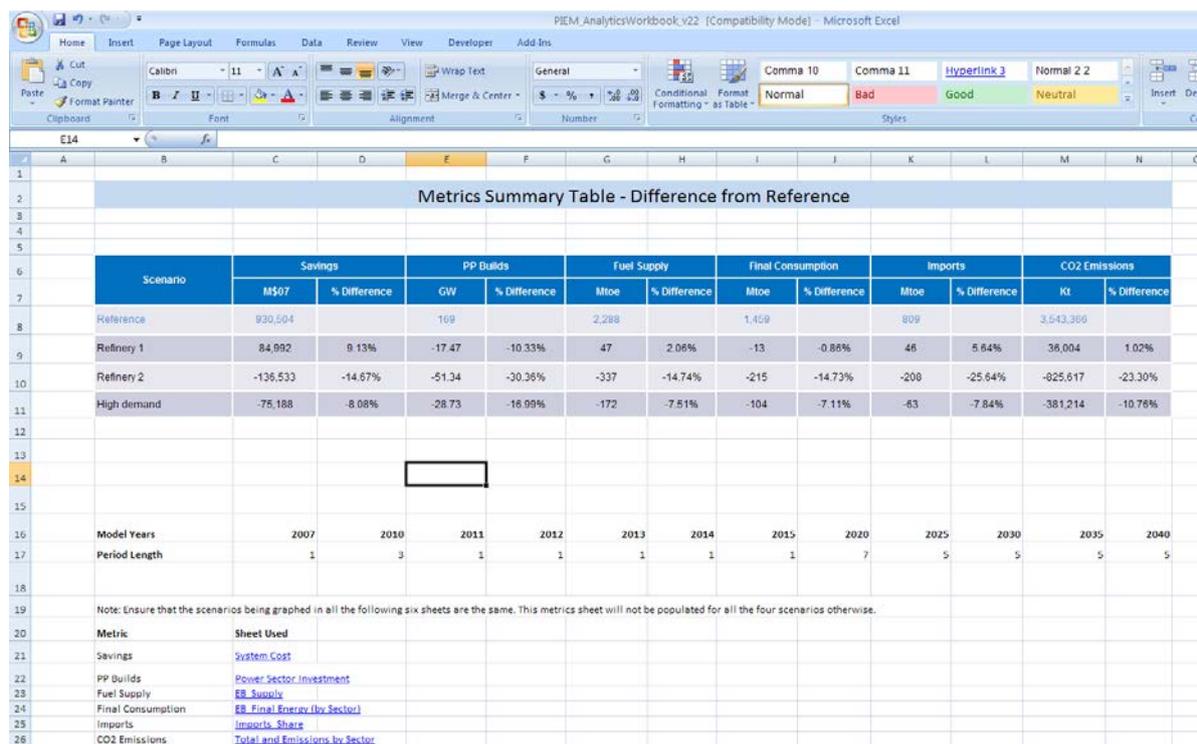


Figure 111: Summary Metrics Worksheet

The metrics sheet also contains the model periods that are being used currently, along with the period lengths. If the user intends to add a metric to this sheet, these model period lengths need to be used to calculate the cumulative sum for any model results that are annual values. This is done using the Excel function – Sumproduct and the appropriate period lengths with the total row from the difference table on the appropriate graphing sheets. Note that if the metric in question is reported as a value per period in the graphing sheets (e.g. PP investment), then the user can simply take the sum of the total row instead of sum-product while populating the metrics sheet.

6. Analytics Workbook Add-in Functions

Each of the above worksheets contains a specific set of functions that allow the user to perform the necessary manipulations with the Analytics workbook. The functions available on each sheet can be accessed by right-clicking according to the sheet type, as reflected in Figure 112, where the rename scenario function is being invoked. Table 13 lists all the available functions, which will be discussed in more details in the following sections. [Note that some of the functions can be run only from specific cells on the sheet].

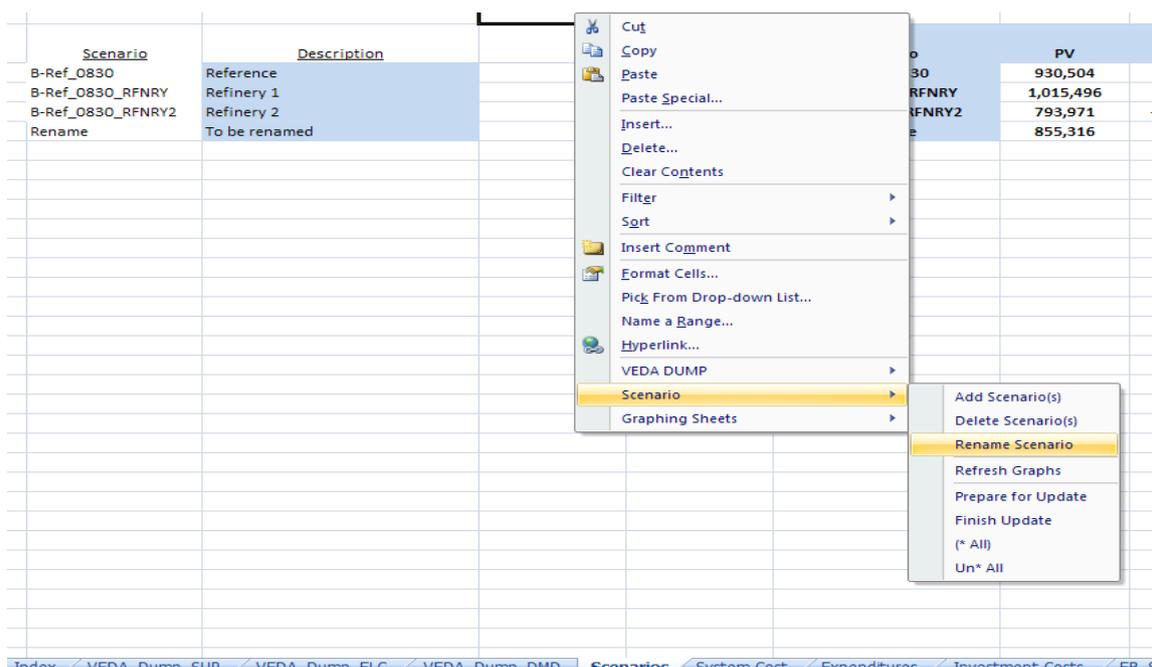


Figure 112: Scenario Worksheet

Table 13: Analytics Add-in VBA Commands

Sheet Type	Function	Description	Cell-specific
VEDA_Dump	<i>Square Table</i>	Ensures each scenario has all rows, determines ensuing table block size, establishes the graphing sheet [requires pre-linking of the graph sheet to the results table]	Can be accessed only from cells containing Table Name in row 5.
Scenarios	<i>Add Scenario(s)</i>	Adds a scenario to every VEDA_Dump table and each Graph sheet	
	<i>Delete Scenario(s)</i>	Removes a scenario from every VEDA_Dump table and each Graph sheet	
	<i>Rename Scenario</i>	Changes a scenario name on all the VEDA_Dump and Graph sheets	Needs to be accessed from cell containing scenario name
	<i>Refresh Graphs - All</i>	Updates the scenarios graphed on all the Graph sheets	
	<i>Prepare for Update</i>	Prefixes "*" to scenarios (so not seen by VBE_Update Excel), removes formatting on VEDA_Dump sheets and sets Formulas to Manual in Excel	
	<i>Finish Update</i>	Remove "*" from scenarios, set Formulas to Automatic	
	<i>(* All)</i>	Puts a "*" in column A for all scenarios	
	<i>Un* All</i>	Remove all "*" in column A	
Graphing Sheets	<i>Add Period</i>	Inserts a period in the graph sheet tables to the right of the last period	Can only be run from the period header cells in the blue area.

	<i>Delete Period</i>	Remove a period from the graph sheet table	Can only be run from the period header cells in the blue area.
	<i>Establish Links</i>	After pointing cell [B7] to the associated VEDA_Dump table name cell [in row 5] does an update to the blue data area links	Can be accessed only from cell B7 on the graphing sheets.
	<i>Refresh Graphs - Sheet</i>	Refresh the graphs on just the current sheet for the requested scenarios	

C. Viewing Results – Controlling Scenarios Graphed

The four scenarios of interest, and the order in which they are presented on the graphing sheets, can be chosen from the “Scenarios” sheet by right clicking on any cell in the sheet and choosing *Scenario/Refresh Graphs*. That will open the command box shown in Figure 113. From the scenario list on the left, first select the four scenarios to be graphed using the > and < buttons and then order the list of scenarios using the UP and Down buttons. Second, indicate which graphing sheets are to be refreshed (usually all) and then click “Refresh Graph.”

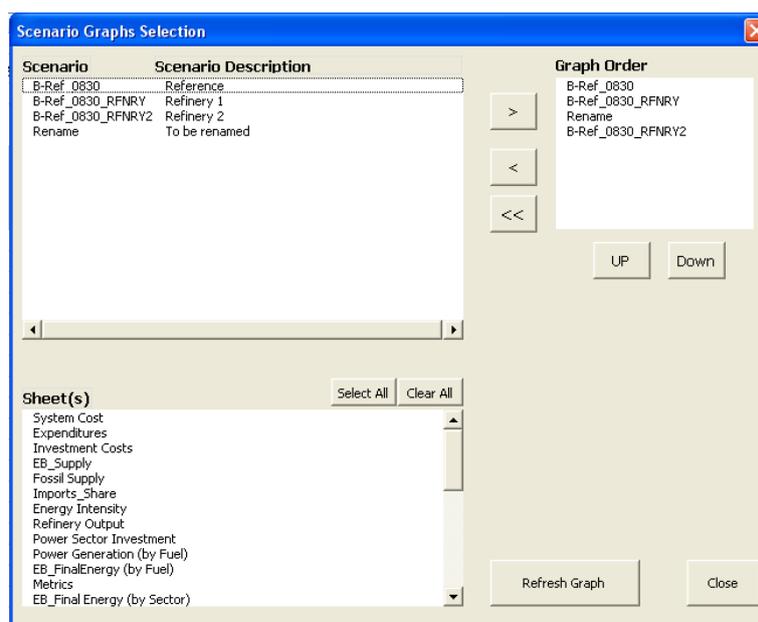


Figure 113: Scenario Graphs Selection Command Box

If, while viewing a particular graph sheet, you would like to investigate particular model results for a different set of scenarios, use the *Graphing Sheets/Refresh Graphs per Sheet* function, which can be brought up by right clicking in any cell on the graphing sheets. That option opens a selection box, shown in Figure 114, in which the desired scenarios can be added or removed (right or left arrows) and their order modified (via up or down buttons). Clicking “Refresh Graph” will update all the charts on that graph sheet only.

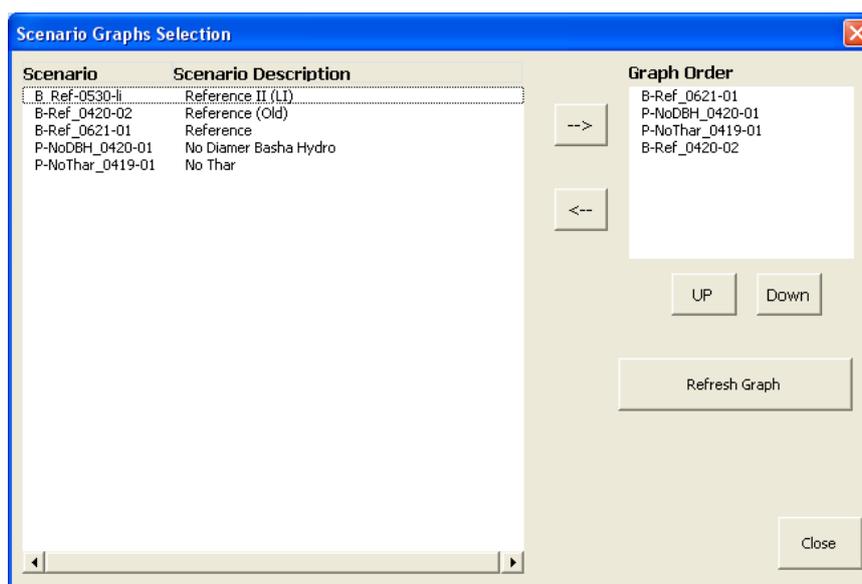


Figure 114: Scenario Selection – Refresh Graphs per Sheet

D. Updating the Workbook

Once an Analytics workbook has been set up with the desired tables, graphs, and scenarios, the most common operation (other than viewing the results), is updating the data tables from VEDA-BE (VBE) as various scenarios are re-run. The steps to be followed while performing such an update are discussed below.

1. Select Scenarios for Updating

In many cases, the user will need to update all the scenarios in the workbook, and this step can be skipped. However, because the Update Excel process in VBE can be time consuming, the Analytics workbook has a feature to allow the user to update only select scenarios.

On the Scenarios tab, mark any scenarios that do not need to be updated with a * next to them in Column A. The user also has the option of inserting a * next to all scenarios using the right-click function (* All) and then deleting the *s next to scenarios that need to be updated, as shown in the two parts of Figure 115.

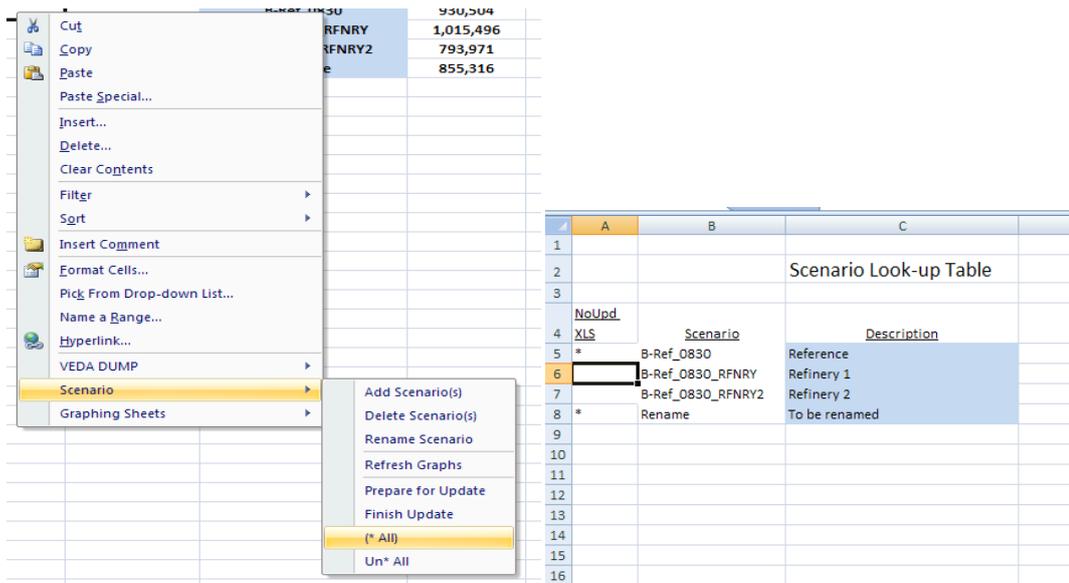


Figure 115: Selecting Scenarios for Updating – (*All) Right Click Command on Left and Result after Deleting Two *s on Right

2. Prepare the Workbook for Updating

The Scenario/*Prepare for Update* function (see Figure 116) performs a number of operations to speed up the update process. It removes all the comments and formatting in the DUMP sheets, attaches “*” to the scenario names for any scenarios that are not being updated and turns the Excel Calculation Options to Manual. Note that if all the scenarios need to be updated, column A should be left blank before running *Prepare for Update*. **Also, it is important to align the list of scenario to be updated with the VBE Global Filter applied to Scenarios.**

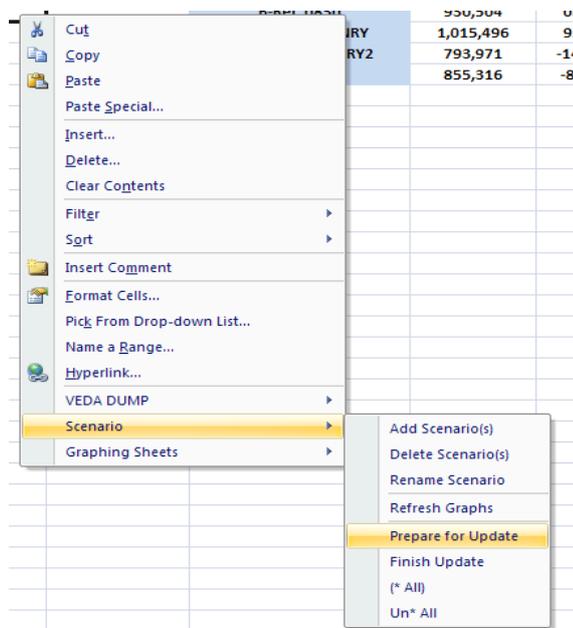


Figure 116: Prepare for Updates Command

3. Run the VBE Update Excel Process

Close the workbook and open VBE to run the update process from VBE (Tools -> Update Excel file -> All Tables) as shown in Figure 117. Before running the update process, make sure a Global Filter is applied that contains all the scenarios that are specified to be updated in the Analytics workbook. **{No other Excel files should be opened while the update process is running.}**

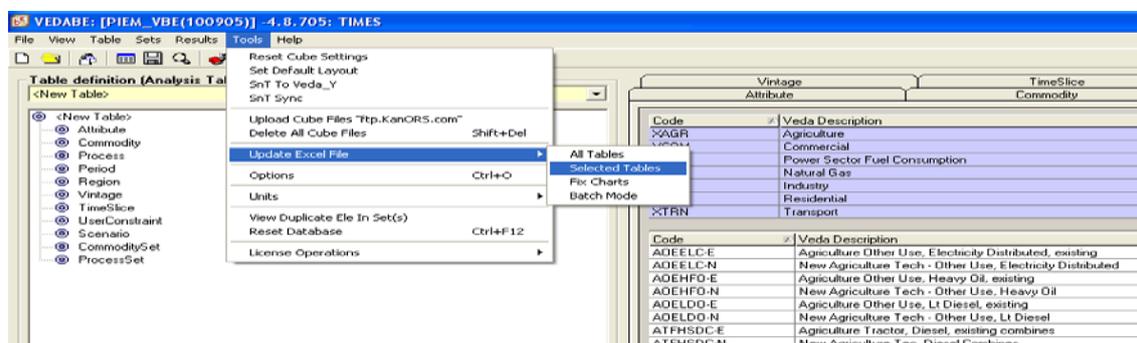


Figure 117: Update Excel File Process in VEDA_BE

The progress of the update process can be seen on the VBE status bar as VBE generates intermediate tables and compares the excel table records for each of the tables present in the Dump sheets. The user can choose to stop the update process at anytime using the “Break” button (See Figure 118).

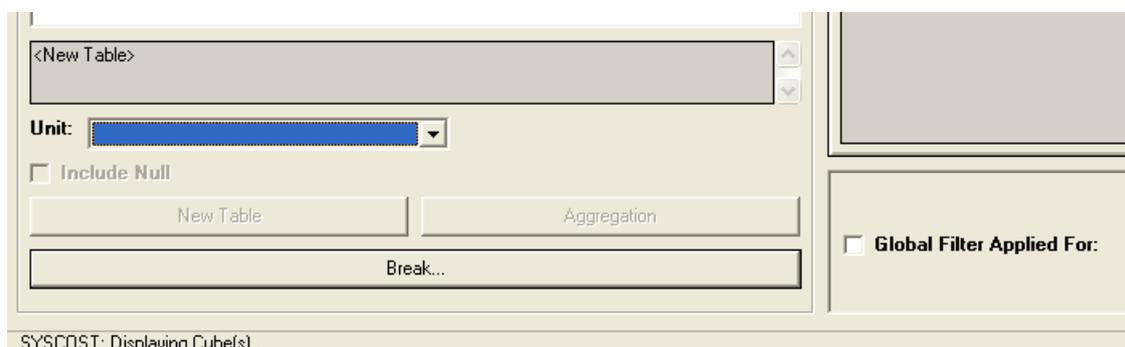


Figure 118: Breaking the VBE Update Excel Process

A VEDA-BE message will indicate the completion of the update process as either successful or encountering some possible anomalies. In the latter case, the user should read the UpdateExcel log and ExtraRecords files to ensure that no tables were missed while updating.

4. Finishing the Update Process

Open the Analytics workbook and run the *Finish Update* function (see Figure 119) to remove “*” from any scenario names and set the Excel Calculation Options to Automatic. This step should be followed by the (*Un* All*) function if needed. It is encouraged to check the VEDA_Dump sheets to ensure that all the desired tables and scenarios are properly updated, as indicated by yellow highlighting in the Table Name cell.

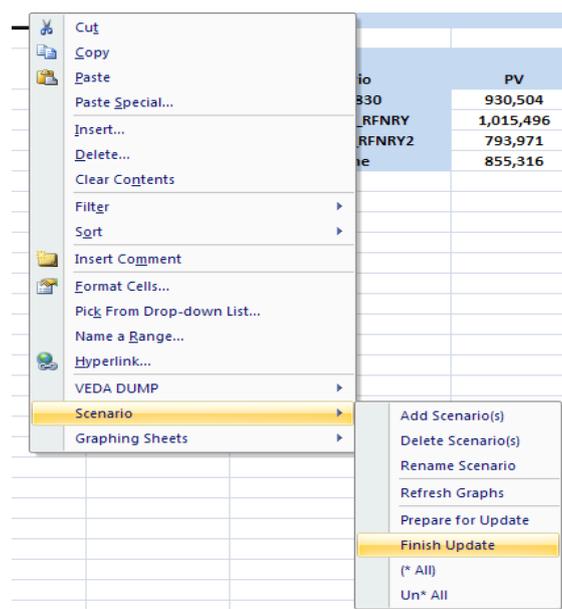


Figure 119: Finish Updates Function

One reason that some of the tables may not have been properly updated is because of differences in the table layout between the workbook and the corresponding VBE table. This may happen if it was mistakenly saved with the wrong layout when exploring the table details by reorganizing the cube. *{Reminder: if a table name appears red in VBE that indicates that it has been used in an Update Excel operation and should not have its layout changed without great care. This is reinforced by user prompts in VBE if a user attempts to save an update table with a different layout.}* If this occurs, the user should go back to VBE, select the table in question, reorganize it to match the layout on the VEDA_Dump sheet, save it again, and then run VBE (Tools -> Update Excel file -> Selected Tables) as appropriate. Other error entries in the VBE ExcelUpdate log file could point to differences in the naming of row qualifiers. The user then needs to ensure that names of the row qualifiers and/or scenarios exactly match the names in the workbook and re-run the update process for all or selected tables.

In addition to the above-mentioned potential errors, the VBE ExtraRecords file could indicate that there are time periods that exist in the VBE tables but not in the workbook. This can be ignored if the user *does not* intend to report the results for these periods from VBE in the workbook (as is the case in Pak-IEM for periods 2008 and 2016 for various annual tables). However, if the user wishes to report these values in the workbook, the VEDA_Dump table will need to be modified by inserting periods and the Graphing sheets by Adding periods and reestablishing links (see Section G) before running the update process.

E. Managing Scenarios

The Pak-IEM Analytics workbook contains the full set of initial policy scenarios, but as part of the normal use of the model to analyze new model runs, it will be necessary to add new scenarios to the workbook, as well as delete old scenarios.

1. Adding New Scenarios

Scenario results from new model runs can be added using the *Add Scenario(s)* function by right clicking on any cell in the “Scenarios” tab and selecting Scenario/Add Scenario(s). This

will open the form shown in Figure 120, which allows the user to enter the names and descriptions of one or more new scenarios (clicking Add after each scenario entry) and then selecting “Add Scenario(s)” to complete the process.

List of Scenarios to be added	
Scenario1	Test Scenario 1
Scenario2	Test Scenario 2

Figure 120: Add Scenario(s) Form

This function will add the new scenarios to all the tables in the VEDA_Dump and Graphing sheets. Once this is done, results corresponding to the new scenarios can be brought into the workbook by running an update for the newly added scenario, or for all the scenarios as described in the previous section.

2. Deleting Old Scenarios

The workbook also contains a provision for deleting scenarios that do not need to be analyzed anymore. Right click on the any cell on the “Scenarios” tab and access the *Delete Scenario(s)* function to bring up the form shown in Figure 121. Select the scenarios that need to be removed from the workbook and click “Delete Scenario(s)”. Multiple scenarios can be selected for deletion using Ctrl+Click on the delete scenario form.

Scenario	Scenario Description	Status
B-Ref_0830	Reference	
B-Ref_0830_RFNR1	Refinery 1	
B-Ref_0830_RFNR2	Refinery 2	
Rename	To be renamed	
Scenario1	Scenario1	
Scenario2	Scenario2	

Figure 121: Delete Scenario Form

Note that the scenario being deleted should not currently be selected for graphing on any of the worksheets. If there is such a conflict (as indicated by a warning message on trying such a deletion), run *Refresh Graphs* for All tables with an appropriate scenario selection (not including the scenarios to be deleted) before running *Delete Scenario(s)* to ensure that the scenario being removed is not being used anywhere in the workbook.

3. Renaming Scenarios

The other useful feature for managing scenarios in the Analytics workbook is *Rename Scenario*. The name of a particular scenario in the workbook can easily be changed using the *Rename Scenario* function. This function can be accessed by right clicking on the chosen scenario (from the list in column B) on the “Scenarios” tab and selecting *Rename Scenario*, which will open the form shown in Figure 122.

Figure 122: Rename Scenario Form

F. Adding New Tables and Graph Sheets

The Pak-IEM Analytics workbook has a well developed set of tables and graph sheets. However, as Pak-IEM is further developed and as new analyses are performed, it very likely that new tables and associated graph sheets will be needed. This section describes the

steps by which these new tables can be created and added to the Pak-IEM Analytics workbook.

1. Create a new Table in VBE

In VBE create the desired table using the required Analytics VEDA_Dump table layout where the cube view of the table is structured in the with the scenario and a single chosen qualifier (e.g. Process, ProcessSet, Commodity, CommoditySet, Attributes, etc.) as rows and time periods as column headers (see Figure 123). The table also needs to report the Total of the chosen qualifier for each scenario.

Original Units: PJ Active Unit Mtoe Data values filter:

Attribute		*Commodity*	*Process*	Region	*Vintage*	*TimeSlice*	Period							
Scenario	ProcessSet						2007	2010	2014	2017	2020	2023	2026	2030
B-Ref_0830	Domestic supply						58	63	71	76	85	84	94	106
	Imports						21	19	21	26	31	50	60	80
	Total						78	82	92	102	117	133	154	186
B-Ref_0830_RFNRY	Domestic supply						58	62	71	76	86	84	95	106
	Imports						21	19	22	26	31	50	59	81
	Total						78	81	93	102	117	134	154	186
B-Ref_0830_RFNRY2	Domestic supply						58	62	70	76	87	85	95	110

Figure 123: Required VBE Table Format for Use with the Analytics Workbook

2. Create the VEDA_Dump Table

In VBE, turn off the Global filter for scenarios and generate a view of the new table so that all of the scenarios are present, and copy the table from VBE cube view (using F7 or via right-mouse click).

Go to the Analytics workbook, and select the appropriate VEDA_DUMP sheet for saving the new table. In that sheet, go to the first open columns to the right, and paste the new table starting on row 5 and ensuring that the new table data is separated by at least one column from all the other tables in the DUMP sheet.

3. Create the New Graph Sheet

Copy an existing graph sheet and rename the new sheet according to the table name.

Link the graph sheet to the corresponding VEDA_Dump sheet table by pointing cell B7 (reading "Scenario") to the cell on row 7 of the VEDA_Dump sheet (containing the word "Scenario") two cells below the new table name. This points the new graph sheet to the new table and will allow data to be updated from in the VEDA_Dump sheet to the graph sheet.

Finally, the time periods for the new table will need to be linked to the values in the first table on the initial VEDA Dump sheet.

4. Square Table Function

Return to the VEDA_Dump sheet and go to the cell containing the Table Name of the new table (in row 5) and do a right click to select *VEDA Dump/ Square Table* (see Figure 124). The *Square Table* function will add rows to the new table as needed so that all the scenarios

in the table have the same set of qualifiers, and thereby number of rows. In addition, this function also sets the block size for the graph data calculations and populates the new graphing sheet with the current table's data.

Table Name: 00	Power Plants NewCapacity			
Active Unit: GW	2011	2012	2013	2014
Scenario	0	0.0348	2.86915	1.348
B-Ref_0830	0	0	0	0
B-Ref_0830	0	0	0	0
B-Ref_0830	1.142	4.5	4.5	6
B-Ref_0830	1454	2.7	2.7	3.6
B-Ref_0830	0	0	0	0
B-Ref_0830	0487	0.0487	0.05193	0.05193
B-Ref_0830	0524	7.28349	10.1211	10.9999
B-Ref_0830_RFNRY	0	0	3.37669	2.28924
B-Ref_0830_RFNRY	0	0	0	0
B-Ref_0830_RFNRY	0	0	0	0
B-Ref_0830_RFNRY	1.142	4.5	4.5	6
B-Ref_0830_RFNRY	2796	2.7	2.7	3.6
B-Ref_0830_RFNRY	0	0	0	0
B-Ref_0830_RFNRY	0487	0.0487	0.05193	0.05193
B-Ref_0830_RFNRY	4703	7.2487	10.6286	11.9412
B-Ref_0830_RFNRY				0
B-Ref_0830_RFNRY	1.283	3.142	4.5	6
B-Ref_0830_RFNRY	0	0.77047	1.56709	2.7
B-Ref_0830_RFNRY	0	0	0	0

Figure 124: VEDA Dump Sheet Square Table Command

5. Establish Links

The charts on the new graph sheet need to be adjusted next by selecting the appropriate data area for each of the four graphs on the sheet. Run the *Establish Links* function from cell B7 of the new sheet once all the graphs are correctly referenced. See Figure 125.

Scenario	Attribute/Desc	Period	2007	2010	2011	2012	2013
B-Ref_0830			1234.24	1614.75	1723.6	1879.82	
B-Ref_0830			4063.31	6147.18	7960.6	10402.4	
B-Ref_0830			10260.8	26383.9	40224.1	55438.2	
B-Ref_0830			15651.9	20143.9	24786.1	29302.4	
B-Ref_0830			31210.3	54289.7	74694.4	97022.8	
B-Ref_0830_RFNR			5055.64	6571.34	8151.21	10186.5	
B-Ref_0830_RFNR			4115.05	6177.71	8001.44	10442	
B-Ref_0830_RFNR			10375.4	26465	40446.1	55646	
B-Ref_0830_RFNR			15432.1	20102.4	24387.6	28618	
B-Ref_0830_RFNR			34978.2	59316.5	80986.4	104893	
B-Ref_0830_RFNR			1224.51	1523.35	1615.26	1716.61	
B-Ref_0830_RFNR			3970.11	5646.21	7035.76	8877.5	
B-Ref_0830_RFNR			9648.2	23899.6	35344	47573.3	
B-Ref_0830_RFNR			15591.7	19474.7	22969.3	26007.6	
B-Ref_0830_RFNR			30434.5	50543.9	66964.3	84175	
Rename			1228.73	1561.96	1664.88	1791.36	
Rename			4010.93	5800.97	7417.53	9569.69	
Rename			9907.72	24837.4	37390.3	51066.4	
Rename			15592.6	19737	23783.7	27561.6	
Rename			30739.9	51937.3	70256.5	89989	

Figure 125: Graph Sheet Establish Links Command

6. Update the Index Sheet

The final step to adding a new table and graph sheet is to add the table name and description to the Index sheet and create the hyperlink to the new worksheet.

G. Editing Time Periods

The last group of functions relate to adding, modifying, and deleting time periods. The functions *Add/ Delete periods* are useful for constructing Graph sheets where the number of periods differs across sheets or when the user intends to view results corresponding to only a subset of periods. This is particularly relevant to Pak-IEM where the model includes a 2008 and a 2016 period, which will not generally be reported in the results. For most tables reporting annual results, the impact of these periods will naturally be reported in the 2010 and 2020 period values. For period results (e.g., new builds, new investment) the results from these periods will be added by post-processing the results into the 2010 and 2020 results.

H. Changing Graph Sheet Periods

Given a table on the VEDA_Dump sheet, the user can alter the number of periods on a graph sheet by running *Add/ Delete Periods* from the period header in the blue area (row 7). See Figure 126. Note that *Add/ Delete periods* could alter the graphs and the difference tables and these would need to be refreshed via the Excel Select Data right-mouse facility once these functions are run.

Scenario	AttributeDesc/Period	2007	2010	2011	2013	2014	2015	2016	2020	2025	2030	2035	2040
B-Ref_0830	Activity cost (Delivery/Varc	2452.95	1234.24	1614.75	1				2888.56	0	0	0	0
B-Ref_0830	Fixed O&M costs	2872.28	4063.31	6147.18	71				19846.4	0	0	0	0
B-Ref_0830	Investment costs (annual)	0	10260.8	26383.9	401				109297	0	0	0	0
B-Ref_0830	Resource supply costs (incl	14396.5	15651.9	20143.9	241				59362.9	0	0	0	0
B-Ref_0830	Total	19721.7	31210.3	54289.7	741				191395	0	0	0	0
B-Ref_0830_RFNRY	Activity cost (Delivery/Varc	6002.44	5055.64	6571.34	811				17221.7	0	0	0	0
B-Ref_0830_RFNRY	Fixed O&M costs	2872.28	4115.05	6177.71	801				19787	0	0	0	0
B-Ref_0830_RFNRY	Investment costs (annual)	0	10375.4	26465	401				109516	0	0	0	0
B-Ref_0830_RFNRY	Resource supply costs (incl	14396.5	15432.1	20102.4	241				59783.9	0	0	0	0
B-Ref_0830_RFNRY	Total	23271.2	34978.2	59316.5	801				206309	0	0	0	0
B-Ref_0830_RFNRY2	Activity cost (Delivery/Varc	2452.95	1224.51	1523.35	161				2264.07	0	0	0	0
B-Ref_0830_RFNRY2	Fixed O&M costs	2872.28	3970.11	5646.21	701				14590.8	0	0	0	0
B-Ref_0830_RFNRY2	Investment costs (annual)	0	9648.2	23899.6	31				83951.6	0	0	0	0
B-Ref_0830_RFNRY2	Resource supply costs (incl	14396.5	15591.7	19474.7	221				40839.4	0	0	0	0
B-Ref_0830_RFNRY2	Total	19721.7	30434.5	50543.9	661				141646	0	0	0	0
Rename	Activity cost (Delivery/Varc	2452.95	1228.73	1561.96	161				2601.98	0	0	0	0
Rename	Fixed O&M costs	2872.28	4010.93	5900.97	741				16600.7	0	0	0	0
Rename	Investment costs (annual)	0	9907.72	24837.4	371				94693.8	0	0	0	0
Rename	Resource supply costs (incl	14396.5	15592.6	19737	231				53416.9	0	0	0	0
Rename	Total	19721.7	30739.9	51937.3	701				167313	0	0	0	0

Figure 126: Graph Sheet Add and Delete Periods Commands

1. Changing Periods on the VEDA Dump Sheets

The PIEM analytics workbook also allows the user to change the labels for the periods from the first VEDA_Dump sheet as indicated in Figure 127. This change will be automatically implemented for all other VEDA Dump tables because of links. The user can then run an update on the workbook and populate it with results corresponding to the desired periods if the MileStoneYRs are changed, but unless periods are added/removed the workbook is currently setup to handle 14 periods, where the 2008/2016 periods are generally not presented on the graph sheets and these levels are summed on those tables involving the reporting of new build investment. Note that any new tables added will need to have their time periods (in row 7 of the VEDA_Dump sheets) referencing the time periods in the first table on the VEDA_Dump sheet.

Scenario	AttributeDesc/Period	2007	2010	2011	2012	2013	2014	2015	2020	2025	2030	2035	2040
B-Ref_0830	COAL	4.42615	4.34077	4.98355	5.85291	7.1259	12.6772	16.68	30.09				
B-Ref_0830	Hydroelectric	7.62662	7.00446	8.51878	13.1098	18.4212	23.7325	30.8143	37.8961				
B-Ref_0830	Natural Gas	29.26	30.15	37.33	36.93	37.02	35.73	37.89	40.41				
B-Ref_0830	Nuclear	0.54615	0.55107	1.11528	5.65944	10.7408	15.8222	22.5974	28.38				
B-Ref_0830	Oil & Products	20.5096	19.29	20.40	21.69	25.93	30.04	32.79	37.33				
B-Ref_0830	Renewables (excl. hydr	15.89	19.6779	19.54	20.1803	20.3956	20.6505	20.9054	19.11				
B-Ref_0830	Total	78.26	81.02	91.90	103.42	119.64	138.66	161.68	193.11				
B-Ref_0830_RFN1	COAL	4.42615	4.34933	5.04305	5.88324	7.00546	13.25	18.40	31.89				
B-Ref_0830_RFN1	Hydroelectric	7.62662	7.00446	8.51878	13.1098	18.4212	23.7325	30.8143	37.8961				
B-Ref_0830_RFN1	Natural Gas	29.26	30.50	37.24	37.36	38.71	36.75	38.44	40.38				
B-Ref_0830_RFN1	Nuclear	0.54615	0.55107	1.11528	5.40548	10.4869	15.5682	22.3434	26.13				
B-Ref_0830_RFN1	Oil & Products	20.5096	19.19	20.75	21.97	26.31	31.31	34.15	42.96				
B-Ref_0830_RFN1	Renewables (excl. hydr	15.89	19.6779	19.5352	20.1803	20.3956	20.6505	20.9054	18.9977				
B-Ref_0830_RFN1	Total	78.26	81.88	92.20	103.91	121.33	141.26	165.05	198.26				
B-Ref_0830_RFN1	COAL	4.42615	4.34077	4.95435	5.86684	6.43954	8.06	8.90	17.40				
B-Ref_0830_RFN1	Hydroelectric	7.62662	6.70485	8.51878	13.1098	18.4212	23.7325	30.81	37.90				
B-Ref_0830_RFN1	Natural Gas	29.26	30.11	35.12	34.24	33.16	31.36	30.54	30.86				
B-Ref_0830_RFN1	Nuclear	0.54615	0.55107	1.11528	2.56331	5.51455	10.5959	17.3711	17.97				
B-Ref_0830_RFN1	Oil & Products	20.5096	19.28	20.22	21.09	24.58	26.15	27.38	29.38				
B-Ref_0830_RFN1	Renewables (excl. hydr	15.89	19.6779	19.96	20.18	20.40	20.65	20.91	21.25				
B-Ref_0830_RFN1	Total	78.26	80.66	89.90	96.85	108.51	120.55	135.91	154.15				
Rename	COAL	4.42615	4.34077	4.95316	5.78199	6.83298	11.14	12.84	24.89				
Rename	Hydroelectric	7.62662	6.70485	8.51878	13.1098	18.4212	23.7325	30.8143	37.8961				

Figure 127: VEDA Dump Sheet Change Periods

Addendum B: Version Control

Version control is critical for any modeling effort, particularly when the team is distributed and collaborating remotely. For Pak-IEM there are three core sets of files that need to be managed:

- VEDA-FE templates containing the model input and source data (and the associated databases), this includes the policy scenarios and other sensitivity files assembled
- VEDA-BE set of database files containing the model run results and the Sets and Tables developed to facilitate the assessment of the model results
- PIEM_Analytics Excel workbook with the model run comparison tables

The procedures outlined here may be assisted by the use of a commercial version control software system. However, the basic steps and procedures will not be impacted – just less manual steps will be needed and tighter control enforced.

A. Core Templates – Basic Procedures

The core set of input templates consist of the B-Y templates (along with *BY_Settings* and *SysSettings*), SubRES (and dummy Trans file), and the Scen_ scenario files that tailor the Reference scenario and establish the Demand projection. In addition there is the Energy Balance and *Template_Scen-ZPolicyRuns* non-VEDA files. Collectively there are 15 Excel workbooks constituting the core model, consisting of 7 BY templates, BY_Trans, SysSettings, NewTech (and dummy _Trans), demand allocation+series, and at least one driver assignment file, REFERENCE scenario files for DMD/ELC/FR and SectorPrices; along with any number of additional Scenario files as needed for analyses. These are described in more detail in Section II.A. All these files reside in a folder, the \VEDA\VEDA_Model\PIEM_TMPL_<date> folder. Thus when looking to freeze and distribute a full Pak-IEM model this folder should be archived (using WinRAR or a similar compression software) with the folder name, and installed in the \VEDA\VEDA_Model folder using the "Add to <folder name>" option. In terms of procedures for managing the individuals templates the approach below is strongly encouraged.

1. The *xModelTemplateTracking_<date>.XLS* should be used to check-out a template for the purpose of making changes.
2. When changes are to be done, the Sector Lead should update the *xModelTemplateTracking* table checking out template(s) to a particular individual indicating the required information and highlighting the person's name with accordingly. [An email should be sent to each of the PT members by the Lead informing all of the transfer of control and pending update.]
3. As changes are done they should be reflected on the Legend sheet indicating the sheet(s) where the changes were made and who is making the change, the file should be saved with the Legend and sheet entries change selected, to the extent possible. The changes should also be colored according to who checked-out the workbook.
4. The individual making the changes should pass them to the Sector Lead, who should introduce the template to the model and test the changes for errors.
5. Upon completion of the testing the Sector Lead is to remove the coloring, update the *xModelTemplateTracking* XLS, post the template, and email the PT.

The Lead Modeler will decide at what point to freeze a particular model instance, and make a new PIEM_TMPL_<date> folder.

B. Policy Scenario Files

The Template-*Scen_ZPolicyRuns_v###* workbook is discussed later in Section 4.D.1. In terms of version control, these files reside in the \VEDA\VEDA_Model\PIEM_TMPL_<date>\SuppXLS folder, and therefore are carried along with all the core VFE files when an archive is made. The only difference is that this template is to be controlled by the Lead Modeler, who may take control and give it to someone for the purpose of developing a new basic scenario that is to be managed with the other *ZPolicyRuns*. [At any time specific other scenarios not using the *ZPolicyRuns* template can be created, as discussed in Section 4.D.2.]

Analysts wishing to use the *ZPolicyRuns* to create a particular sensitivity case should simply 1st save it with a *Scen_Pol<name>* and then customize as necessary. Thus a looser version control is applied to the *Scen_Pol<name>* files, though following the guidelines mentioned above is advisable anyway.

C. VEDA-BE Databases and SnT File

The VEDA-BE database reside in the \VEDA\VEDA_BE\Databases\PIEM folder. The folder will contain several database (MDB) files, the *VEDA_S/R* internal files, the *VEDA_SnT* Sets-and-Table file with the user defined set and table definitions, and a series of *VEDA_R_<scenario>* files containing the results from each model run being handled by VBE at the time. The key file among these is the SnT file.

When an analyst wants to add a new Set or Table that is to be shared with everyone, s/he should contact the Lead Modeler and request control over the SnT file. Any Sets or Tables added are to be summarized when returning the SnT to the Lead Modeler, who can check that the new sets and tables are functioning properly and then distribute the new SnT file to everyone on the team. The team members can then:

- Simply replace (overwrite) the current *VEDA_SnT* on their computer with the new file (with VEDA-BE closed), or
- If the person(s) receiving the file has made changes to their Sets or Tables definitions they wish to keep, use the VFE Sets/Import/Access option to bring in only selective SnT entries, as discussed in Section III.B.C.

Note that the VEDA-BE Database folder does not have <date> in the file name like the *VEDA_Models* folder does. This is due to the fact that VFE points to this folder to connect with the VBE *VEDA_SnT* file (by means of the Options/File Location tab), and if the folder name changes, then the VFE database would need to be informed of the new file name.

Before a new VBE database folder is distributed, the Lead Modeler should check that the documentation is complete and then RAR the VBE database folder (*PIEM_VBE*) with an archive name of *PIEM_VBE(<date>)* When the new VBE database is distributed, it is recommended that the receiving team members:

- Rename their existing *PIEM_VBE* folder to *PIEM_VBE(<date>)* to freeze it.
- Save the RARed copy of the new *PIEM_VBE* folder in their VBE Databases folder.
- Unzip the RAR using “Extract here.”
- If done properly, the extracted folder will have the name *PIEM_VBE*.

D. PIEM Analytics Workbook

The *PIEM_Analytics_v###_<study>(date)* workbook resides in the *PIEM_VBE* folder, so it is archived along with the VBE database files as described above.

However, there are three aspects of the Analytics workbook that need to be kept track of; the VBA Add-in that provides the basic right-mouse functions used throughout the workbook is discussed in Appendix A. First, the Lead Modeler has responsibility for ensuring that the code is current and being used by the Planning Team members.

The second aspect is when someone wants to add a new table to the *PIEM_Analytics* workbook. In this case the analyst should 1st request control of the VBE SnT file, as discussed above, then add the new table to VBE and the workbook, updating the Index sheet as necessary. The Lead Modeler will then test the changes and decide if the *_v##* of the workbook is to be incremented, or just a *_v##i* added. Note that the SnT will have to be distributed along with the new *PIEM_Analytics* workbook.

The third aspect is when a study or report has been completed. In this case the results workbook needs to be frozen, as was described for the *PIEM_VBE* folder in general.

Addendum C: Pak-IEM Exercises

This addendum is designed to reinforce the material presented in this Users' Guide by presenting a series of exercises designed to test how well a new user has learned and understood the material presented in the User's Guide and thereby the Pak-IEM. The addendum presents a series of questions and answers that are meant to be answered by new Pak-IEM users working directly with VEDA hands-on. In the first part, a series of questions are presented, and responses are provided in the second part. The material presented here can be administered as a quiz, or the questions can simply be addressed by new users on their own as exercise to test their absorption of the material in the User's Guide,

It should be noted that because Pak-IEM and VEDA are "living" systems, the screenshots and even the numbers reported in this exercise may **not** match the current look of VEDA or the information in Pak-IEM. However, the process necessary to address the various questions and carryout the exercises presented here remains essentially the same.

A. Pak-IEM Questions for New Users

1. Templates

1. In what folder does the *PIEM_TMPL_<date>* RAR file belong when distributed?
2. How do you change the model you are working with?
3. How many different groups of workbooks does VEDA handle?
4. How do you open the folder associated with a template group?
5. In which workbook are the model regions, sectors, periods and timeslices defined?
6. How many Base Year templates are there in Pak-IEM?
7. What sheets contain the declarations for the RES components?
8. What is the role of *~FI_T* in the templates? What is to the left (and to the right) of *~FI_T* beginning on the row below the header and comment line?
9. How are units entered into the model? Show the units for any technology in VEDA.
10. Which templates contain the power plants, refineries and cars, respectively?
11. What are the 4 ways to make changes in a template?
12. For each of the 4 ways to make a change in a template what must you do to have the change entered into the VEDA Database?

2. Browse

1. What is the difference between the 2 views for examining the data via Browse?
2. How many selection criteria windows does Browse provide? Which ones are used most often and for what purpose?
3. What are the 2 ways to limit the lists in the Browse selection windows?
4. What are the 2 ways to select items in the lists?
5. How can you tell how many items are currently selected in a list?
6. What is, and what is the importance of, the SnT reference at the very top of the VFE form? How is it associated with VFE?
7. What information does the YEAR-0 column handle?
8. What are the qualifiers for each row in the Browse table below?

Process	Attribute	Scenario	Year 0	Year 2007
ERHYDDAM-Akhor-N	AFS	NewTechs		1.62
	CAP2ACT	NewTechs	31.54	
	CAP_BND	NewTechs		0.60
	SysSettings		15.00	
	DISCRATE	NewTechs		0.10
	EFF	NewTechs		0.34
	FIXOM	NewTechs		53.19
	INVCOST	NewTechs		5176.47
	PoHydroCostInc			5694.12
	Life	NewTechs		50.00
	NCAP_ILED	NewTechs		4.00
	PEAK	NewTechs		1.00
	START	PoHydroDelay	2025.00	
	Start	NewTechs	2020.00	
	VAROM	NewTechs		1.43

9. What are the different “state” indicators for dimensions moved above the data cube, and what does each indicate?
10. What happens when you double-click on a data cell in the cube?
11. How can you “jump” directly to the process or commodity master?
12. How can you “jump” direction to the RES for a process or commodity?

3. Network Views

1. What are the 3 ways to view the underlying RES connectivity?
2. How can you tell whether a process is output or input normalized?
3. What fuels are used for commercial heating? {Numerous ways to find out.}
4. How many existing power plants consume only natural gas?

5. How many different “steps” (including X-processes) does natural gas go through before it is consumed in power plants?

4. Pak-IEM Data Queries

1. Which province has the most oil reserves? {Try to draw a bar chart!}
2. How many existing hydro power plants are there? {There are numerous ways to find out.} What is their total installed capacity? {Try using Excel to total the capacity!}
3. How many cars are in the model?

5. Tools for Examining Results

1. How do you bring the results into VEDA-BE?
2. What are the key features available in VEDA-BE for controlling how results are examined?
3. How is the main VBE form apportioned?
4. What do the tabs on right correspond to?
5. What is on the top half of the Process tab?
6. What three ways can you see the “rule” associated with a set?
7. How can you tell what table a process set is used in?
8. Global Filters
 - a) What is the purpose of the Global Filter?
 - b) What 2 ways can you select elements for a Global Filter?
 - c) For what tab do you most often use Global Filters?
 - d) How can you tell if a Global Filter is active?
 - e) How do you turn it off, temporarily?
9. How do you set the units for a table? How do you convert them to some other compatible unit?
10. Create a new Process set comprising all the Hydro power plants. Use it to create a new table with all the data associated with just those plants.
11. How can you easily view the flows in/out of a process, and cascade through the RES? {2 ways}
12. How can you retrieve multiple tables via a single request {2-ways}

6. Calibration Run Results

1. What is the total amount of domestic supply (including renewables)?
2. Which refinery produced the most LDO [NB. changed from LSD]?
3. How much natural gas is consumed in the power sector?
4. What is the total installed hydro capacity?
5. How much electricity is generated from hydro plants in the summer day timeslice?
6. What sector is consuming the least amount energy, and what is the level?
7. How much gasoline is consumed in the transportation sector?
8. What is the total energy consumption in industry?

9. How much electricity is consumed in the commercial sector?
10. What is the price of natural gas in the pipeline, and delivered to the commercial customers?
11. What is the total amount of domestic oil produced?
12. What is the total amount of imported oil products?

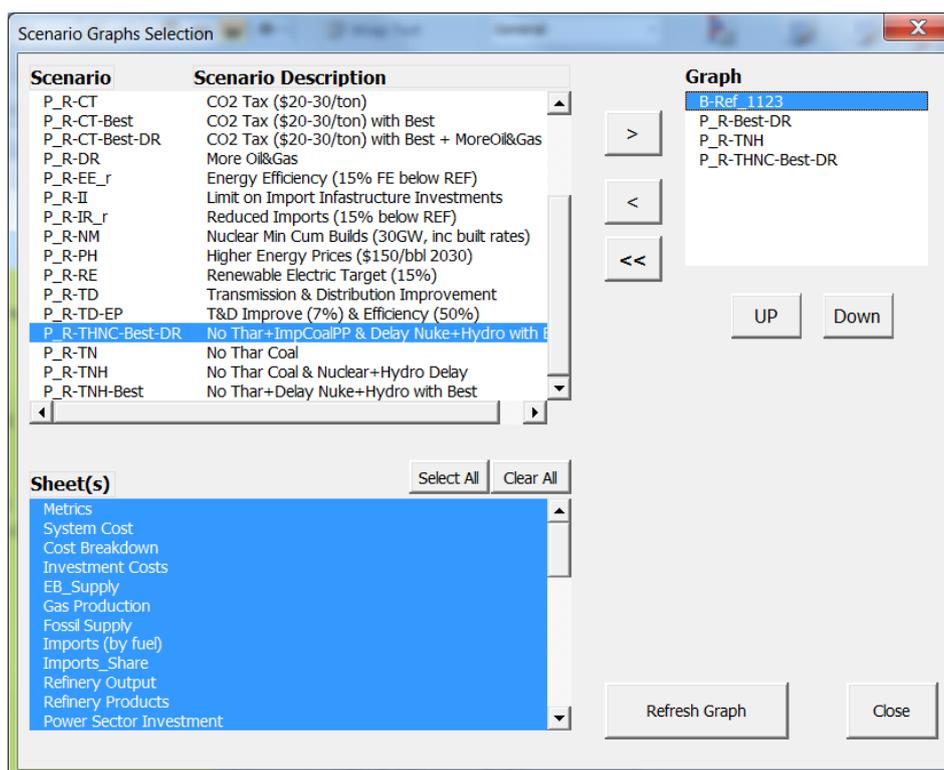
7. Reference Scenario Model Results

This section relies primarily on the use of VBE, in concert with the exporting of the data cubes to Excel, it identify particular results associated with the Reference scenario,

1. What is the total cost of the Pakistan energy system over the 2040 modeling horizon?
2. By how much does the share of imports in total supply change in 2030 compared with 2007?
3. Which supply option increases the most (ktoe) between 2007-2030?
4. What is the total amount of new power plants built over the entire planning horizon? In which period prior to 2030 is the most built, and in said period what particular type of power plants leads the new builds?
5. How much (percent) does electricity generation increase by 2030, and explain the shift in electricity generation mix between 2007 and 2030?
6. By what year will Pakistan need more than 15Mtoe of additional product output from a new refinery, and in said year what product dominated production?
7. Which demand sector has the biggest increase between 2007-2030 in ktoe and in percent of total?
8. Which demand sector consumes the most electricity in 2030 (BKwh), and what percentage of the total does it require?
9. In which period is total gas consumption the lowest, and what is that value?
10. What is the annual expenditure on the energy system in 2030, and what percentage increase occurs in the resource supply costs by 2030?
11. What is the purpose of the AU_ELC user constraints, and what do the marginal values tell us?

8. Sensitivity Scenario Model Results

This section relies primarily on the use of Analytics Excel workbook to examine and compare various model results, while reinforcing how to use the workbook. Setup the workbook to compare the 4 cases shown below (REF, REF-Best+DR, NoTNH, NoTNH-Best+DR) to answer most of the case comparison questions.



1. Which model run has the lowest overall system cost?
2. What happens to total imports when for the 3 sensitivity runs?
3. Which 2 fuel needs to step in for the no/delay cases, by how much in 2030 in the delay but no Best practices case, and what amount of natural gas is saved under Best practices and what is the additional renewables in 2030?
4. How much is saved starting in 2030 each year on the expenditure for fuel when following Best practices?
5. How many GW less new capacity is installed in each of the three alternate scenarios?
6. How many less GWh of electricity are required per annum under each alternate scenario in 2025?
7. Discuss the impact on electricity prices in 2025 for each scenario?
8. Which sectors increase their consumption of natural gas in response to the delay in the large power plant projects, and how much more is needed total in 2030 in the delay scenario without Best?
9. What is the increased renewables to the Residential sector used for?
10. What is the impact of the No Thar/delay on the contributors to CO₂ emissions?

B. Answers⁹ to the Pak-IEM Questions

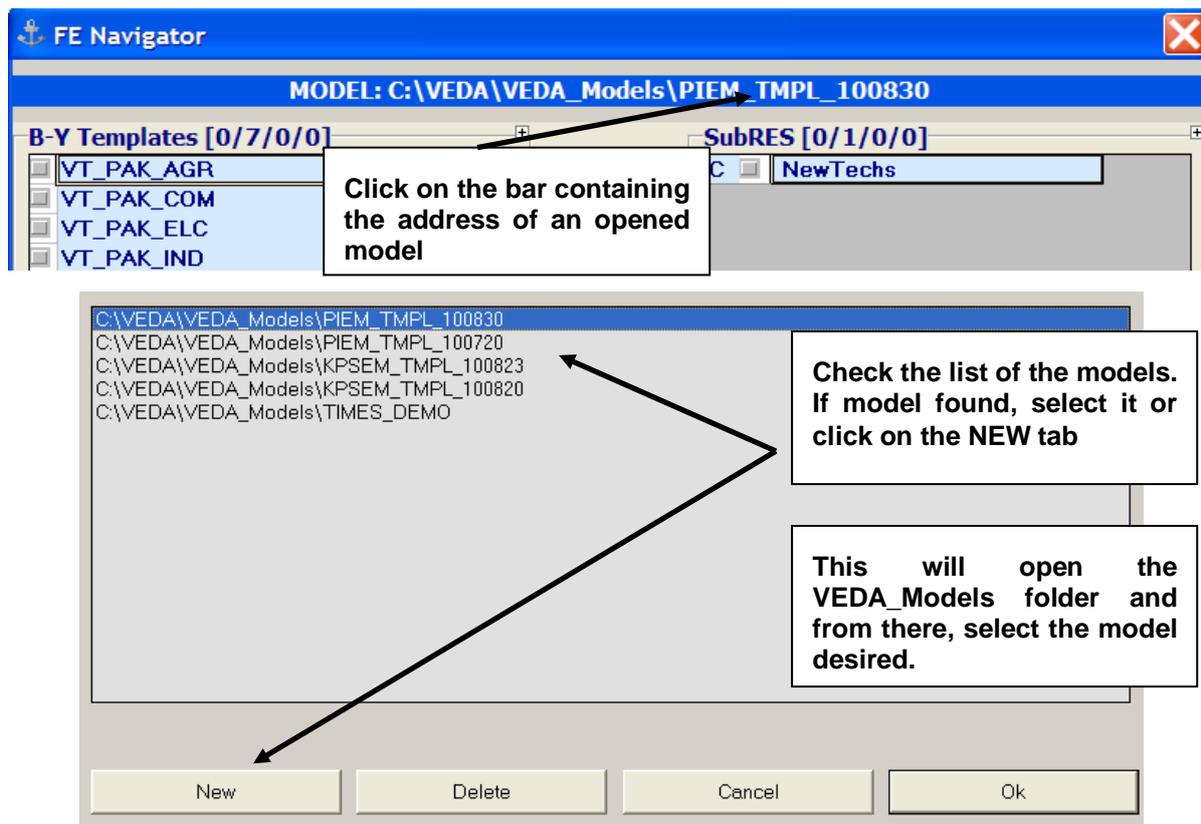
1. Templates

1. In what folder does the PIEM_TMPL_<date> RAR file belong when distributed?

The ...\\VEDA\\VEDA_Models folder is where the PIEM_TMPL_<date> RAR file should be saved. Use the Extract Here RAR command to create the folder for the model templates.

2. How do you change the model you are working with?

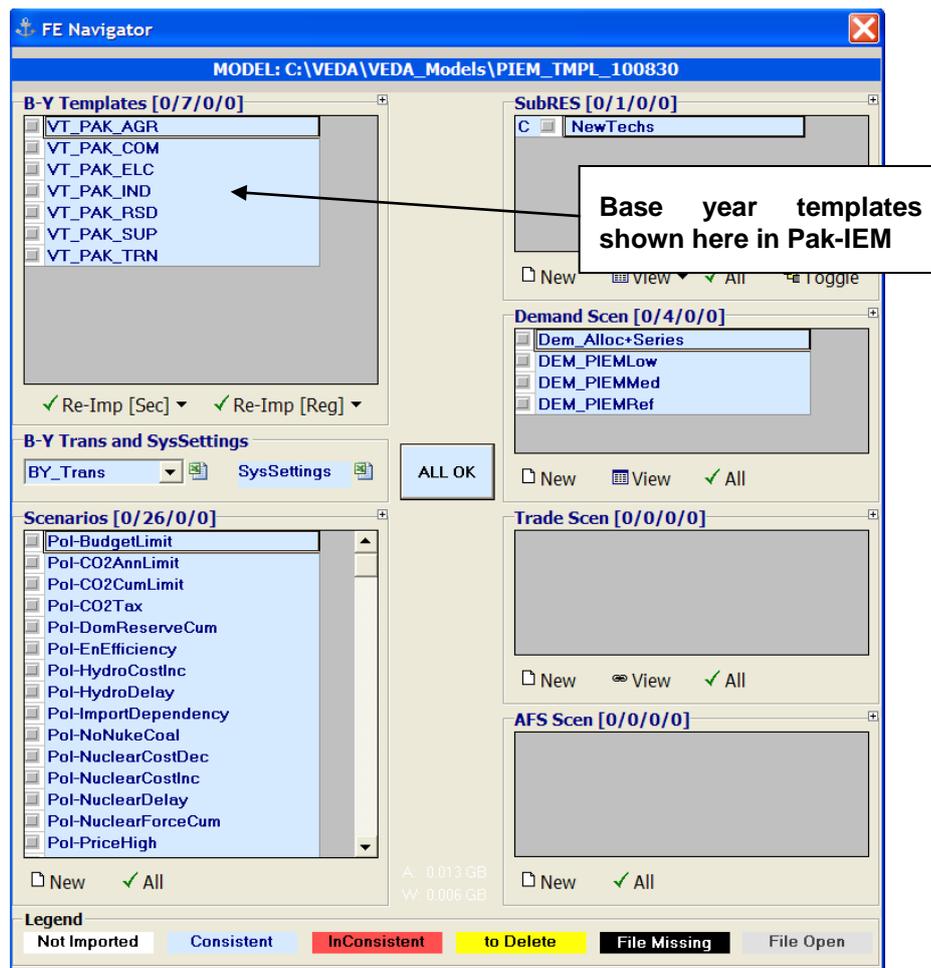
By clicking on the MODEL: {*Template Path*} bar at the top of the FE Navigator, selecting a model already in the list, or by clicking 'New' to browse and select a new model.



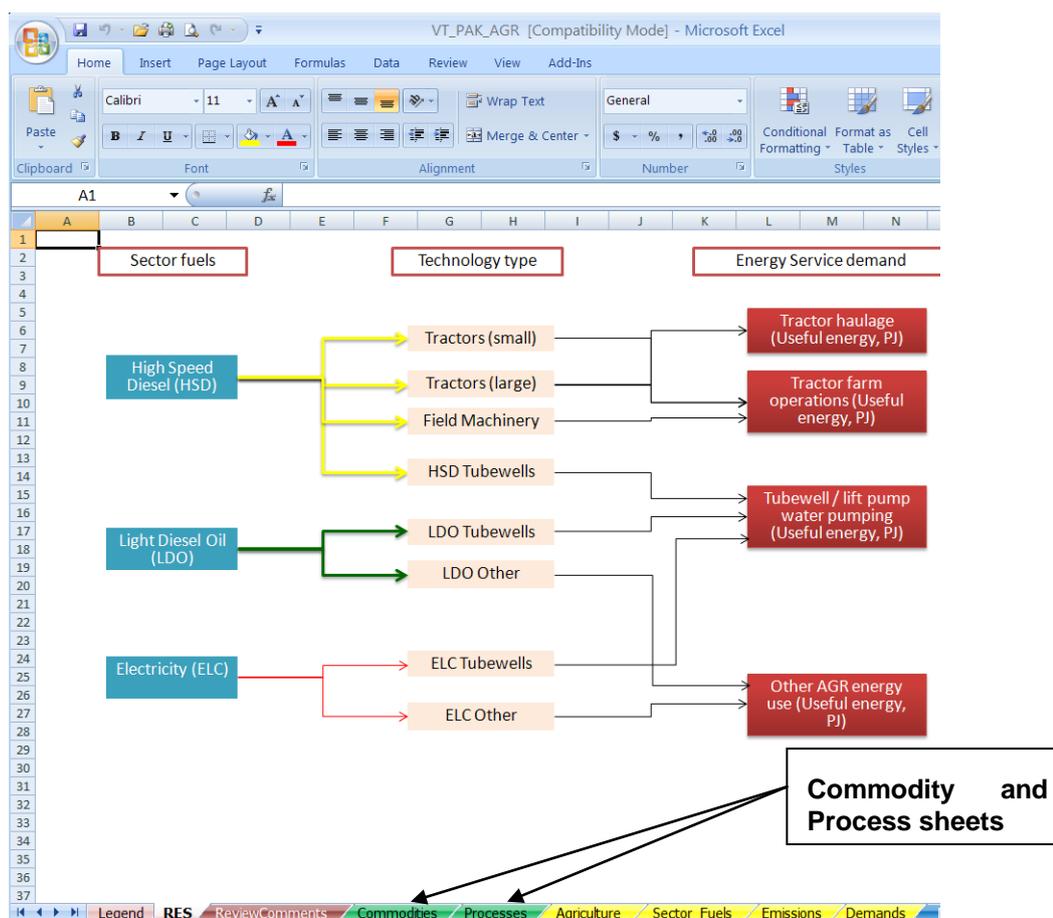
3. How many different groups of workbooks does VFE handle?

Seven, as indicated by the blue bold headers on the FE Navigator (see below). [Note that Pak-IEM does not use groups 6 or 7.]

⁹ The answers provided in this Exercise Solutions document are based largely on a successful and very comprehensive response by the PAEC members of the Planning Team. Note that examples and in particular results are only illustrative as the model is constantly evolving.



7. What sheets contain the declarations for the RES components?
Processes and Commodities.



8. What is the role of ~FI_T in the templates? What is to the left (and to the right) of ~FI_T beginning on the row below the header and comment line?

This is a VEDA Flexible Input Table flag indicating that this table is to be loaded into VEDA-FE for use in the model. To the left of ~FI_T beginning on the next row is the qualifier fields identifying an individual model component, and to the right are the model attributes.

9. How are units entered into the model? Show the units for any technology in VEDA.

Units are entered in the process and commodity definition sheets. However, the units are NOT managed by VEDA or TIMES and are thereby essentially comments. The user has the full responsibility to set the actual units for each attribute and to ensure that all data entered into the model templates is consistent with those units.

~FI_Process	Sets	TechName	TechDesc	Tact	Tcap	TsM	PrimaryCG	Vintage
! Set Membership	Technology Name	Technology Description	Activity Unit	Capacity unit	Timeslice Operational Level	Operational Commodity Group	Vintage Tracking	
PRE	XAGRHS00	#REF!		PJ	PJa	DAYNITE		
	XAGRLO00	Existing Fuel Tech - Lt Diesel (AGR)		PJ	PJa			
	XAGRHO00	Existing Fuel Tech - Heavy Oil (AGR)		PJ	PJa			
	XAGRELC00	Existing Fuel Tech - Electricity Distributed (AGR)		PJ	PJa			
	XAGRBI000	Existing Fuel Tech - Biomass (AGR)		PJ	PJa			
DMD	AWPLD01E	Agriculture Water pumping, Lt Diesel, existing		PJ	PJa			
	AWPHSD1E	Agriculture Water pumping, Diesel, existing		PJ	PJa			
	AWPELC1E	Agriculture Water pumping, Electricity Distributed, existing		PJ	PJa			
	ATHHSD1E	Agriculture Tractor, Diesel, existing - >55hp		PJ	PJa			
	ATHHSD2E	Agriculture Tractor, Diesel, existing - <55hp		PJ	PJa			
	AOEELC1E	Agriculture Other Use, Electricity Distributed, existing		PJ	PJa			
	AOELD01E	Agriculture Other Use, Lt Diesel, existing		PJ	PJa			
	AOEHF01E	Agriculture Other Use, Heavy Oil, existing		PJ	PJa			

Units used for technologies

10. Which templates contain the power plants, refineries and cars, respectively?

For existing technologies, these are characterized in the VT_Pak_ELC, VT_Pak_SUP and VT_Pak_TRN templates, respectively. For new technologies they can be found on associated sheets in the *NewTechs* SubRES file.

11. What are the 4 ways to make changes in a template?

- Directly in the template via Windows Explorer.
- Opening the template via VFE Navigator.
- In VFE Browse, use Direct Edit.
- In VFE Browse double-click on the value you want to change and make the edit in the template.

12. For each of the 4 ways to make a change in a template what must you do to have the change entered into the VEDA Database?

- Save and refresh the FE Navigator (using F5), then click on the SYNC button.
- Save and refresh the FE Navigator (using F5, if necessary), then click on the SYNC button.
- Nothing, the change is applied to the template and database.
- Save and refresh the FE Navigator (using F5), then click on the SYNC button.

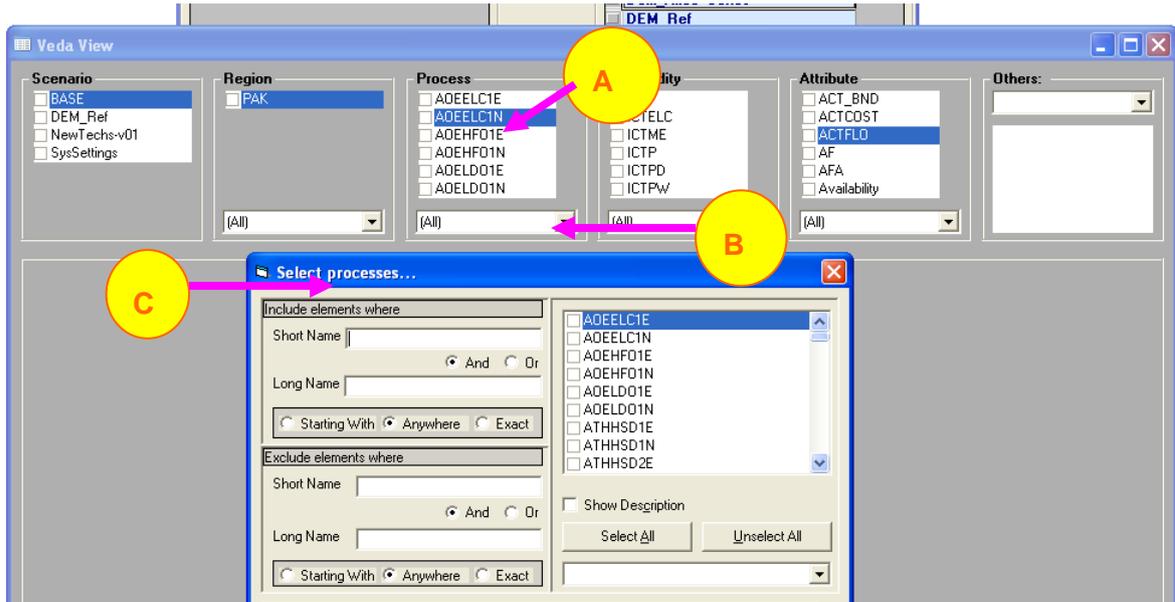
2. Browse

1. What is the difference between the 2 views for examining the data via Browse?

TIMES-view will name attributes as used in TIMES, whilst VEDA-view will use the VEDA specific naming convention as found in the templates. Most often for Pak-IEM the user will work with VEDA-view. The one exception is when needing to examine User Constraints (UCs).

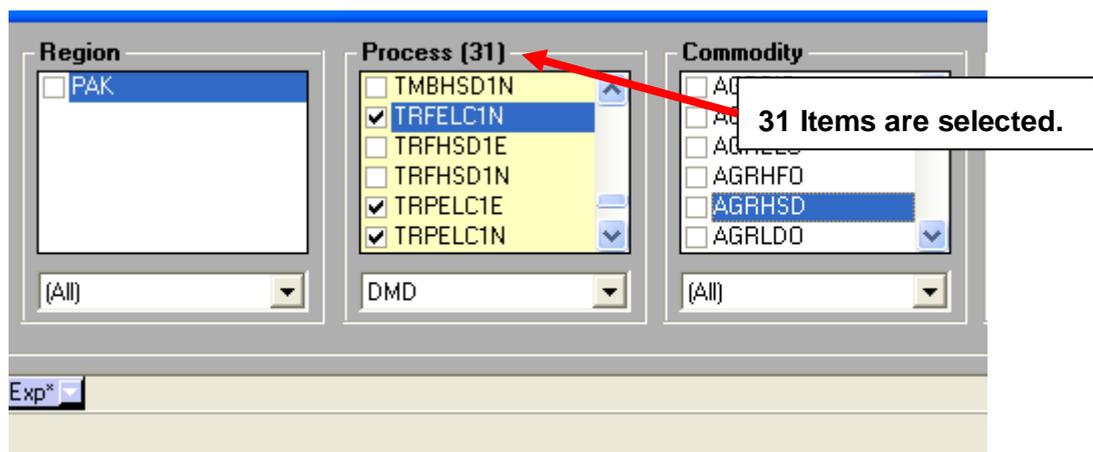
2. How many selection criteria windows does Browse provide? Which ones are used most often and for what purpose?

There are 6 selection criteria windows, as indicated by the bold headers and associated list of items in the Browse view. The Process window is used most often to view the information associated with a single technology or group of technologies.



3. What are the 2 ways to limit the lists in the Browse selection windows?
 - a) Using the drop down lists below the selection windows (see “B” above).
 - b) By right clicking (or pressing [F3]) to bring up the search selection window and choosing the desired items via a “rule” (see “C” above).
4. What are the 2 ways to select items in the lists?
 - a) Checking an item directly (see “A” above).
 - b) By using the search function (see “C” above).
5. How can you tell how many items are currently selected in a list?

By looking at the bracketed number by the selection window header.



6. What is, and what is the importance of, the SnT reference at the very top of the VFE form? How is it associated with VFE?

The SnT reference is located on the Menu bar to the right of the VFE version number, in faded text. The SnT file contains all of the Sets and Tables used in VEDA-BE, and for Pak-IEM this should always specify VEDA_BE\Databases\PIEM_VBE\Veda_SnT.Mdb. These Sets can also be used as filters for the Process and Commodity lists, and as sets

in the templates when specifying qualifiers in Scenario files. It is associated with VFE by means of the Tools/User Options/File Location.



7. What information does the YEAR-0 column handle?

Interpolation override for the associated attribute. [This is most often specified for bounds and User Constraint RHS to extend values out over the model horizon (e.g., 2 if 0 going forward, 5/12 to keep the same value (see the discussion of Interpolation Rules Section II.D.2), though many other instances may also occur.]

8. What are the qualifiers for each row in the Browse table below?

- Process, which currently shows the new hydro plant – Akhor.
- Attribute, which list all the attributes specified for this process.
- Scenario, which specifies the template where the data originates.

			Year	
Process	Attribute	Scenario	0	2007
ERHYDDAM-Akhor-N	AFS	NewTechs		1.62
	CAP2ACT	NewTechs	31.54	
	CAP_BND	NewTechs		0.60
		SysSettings		15.00
	DISCRATE	NewTechs		0.10
	EFF	NewTechs		0.34
	FIXOM	NewTechs		53.19
	INVCOST	NewTechs		5176.47
		Pol-HydroCostInc		5694.12
	Life	NewTechs		50.00
	NCAP_ILED	NewTechs		4.00
	PEAK	NewTechs		1.00
	START	Pol-HydroDelay	2025.00	
	Start	NewTechs	2020.00	
VAROM	NewTechs		1.43	

9. What are the different “state” indicators for dimensions moved above the data cube, and what does each indicate?

- * – where multiple values are contained, and the aggregate of these values displayed.
- ~ – where elements have been removed/filtered from the full list.
- None – where there is a single value only.

10. What happens when you double-click on a data cell in the Browse table?

That depends whether VFE is in Direct Edit mode or not.

- If not in Direct Edit mode – the associated template is opened at the corresponding cell.
- In Direct Edit mode (the data cells will be colored yellow) – a dialog box appears that permits editing the value directly in the database and simultaneously updating the corresponding location in the template. Direct edit provides the option of retaining the

previous value and including a comment. [Note that if the corresponding cell contains a formula the user is given a warning.]

11. How can you “jump” directly to the process or commodity master?

Right click on the process or commodity name, and select “Process information” or “Commodity information,” respectively.

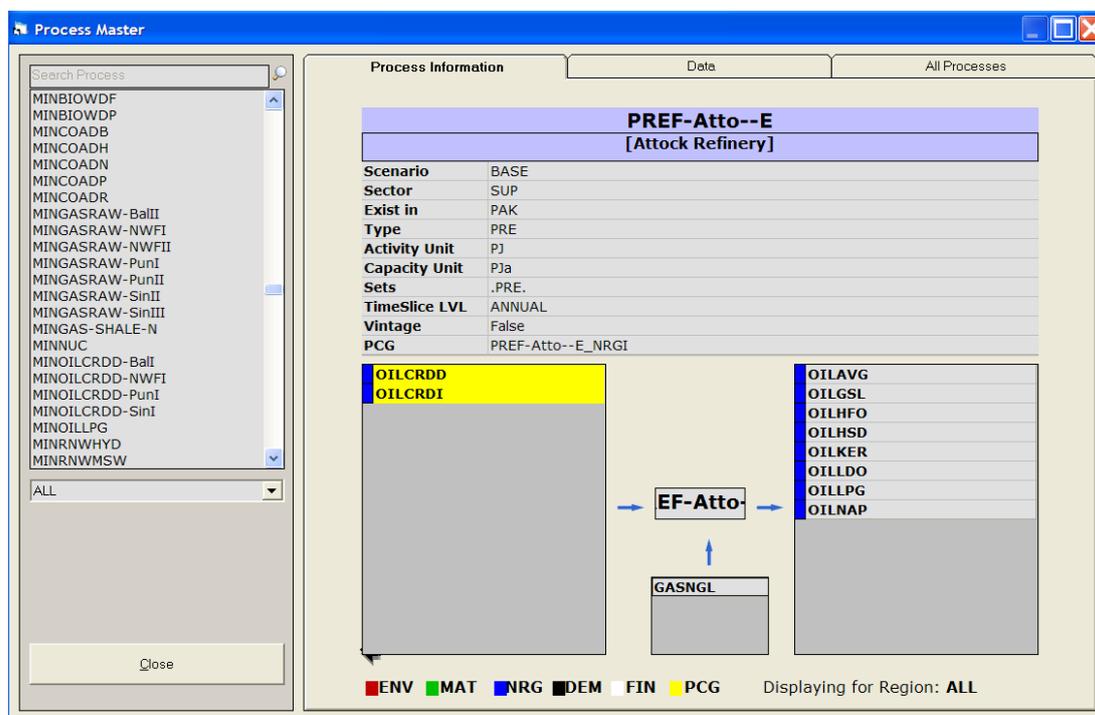
12. How can you “jump” direction to the RES for a process or commodity?

Right click on the process or commodity name, and select “Goto RES”.

3. Network Views

1. What are the 3 ways to view the underlying RES connectivity?

- Press F8 or via Basic Functions select RES or via right mouse in browse select Goto RES.
- Use the Process Master to see the flow in/out of a process.
- Use the Commodity Master to see all the producers/consumers of a commodity then cascade through the RES by clicking on the commodity/process of interest.

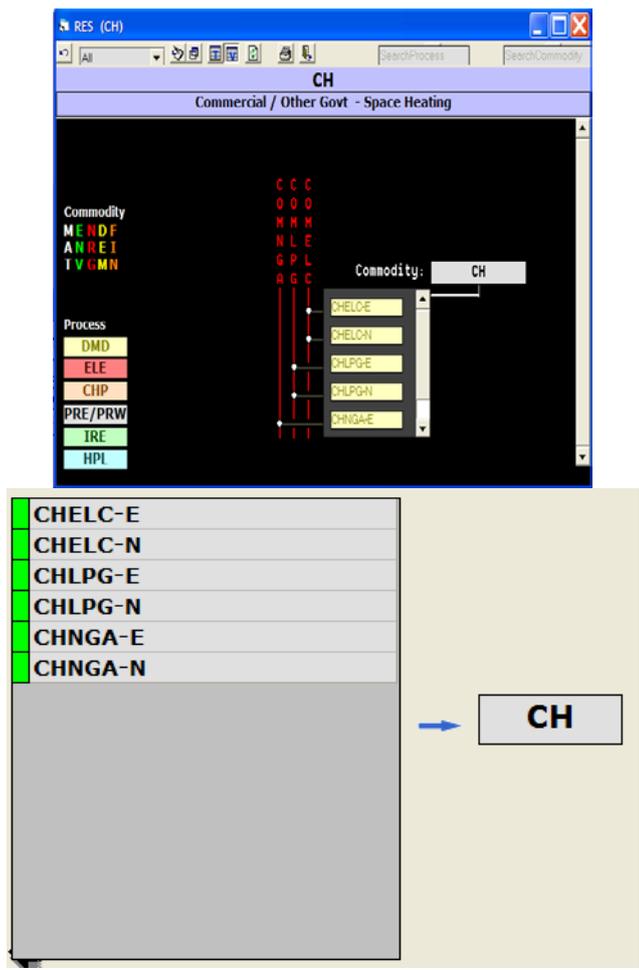


2. How can you tell whether a process is output or input normalized?

By checking the Process Master to see whether a process input or output commodity(s) has been defined as the Primary Commodity Group, as indicated by the PCG members in yellow.

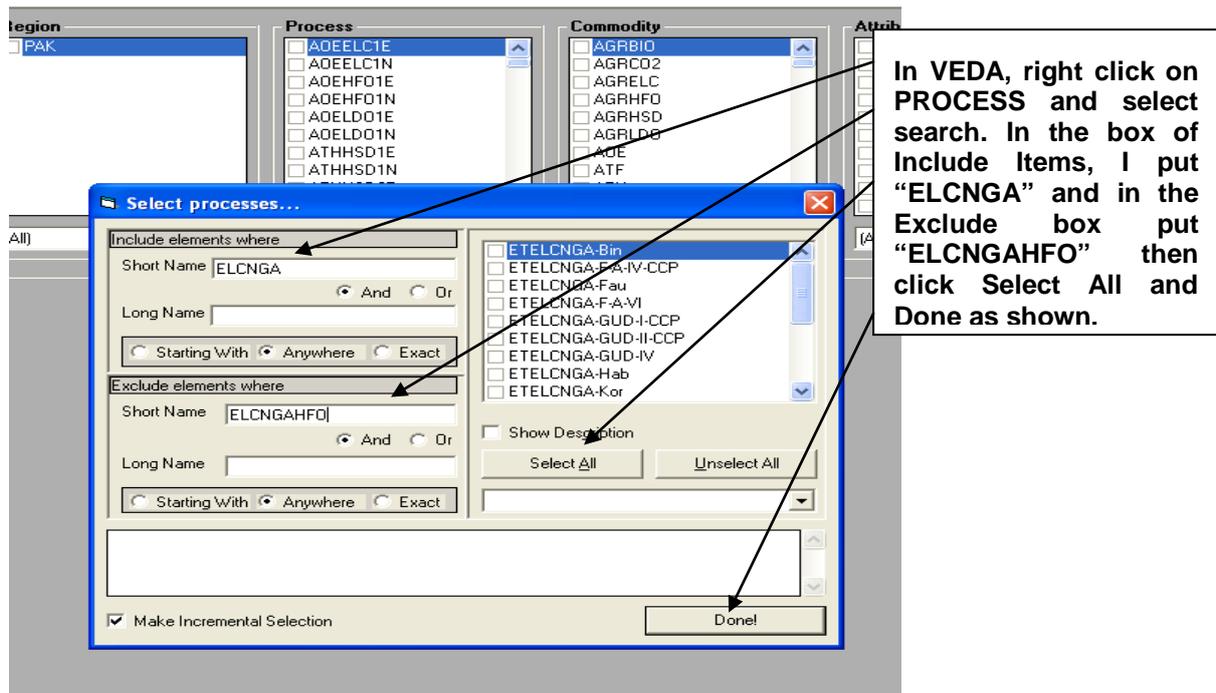
3. What fuels are used for commercial heating? {Numerous ways to find out.}

Gas, LPG, and electricity, as identified through the RES or Commodity Master (shown below).



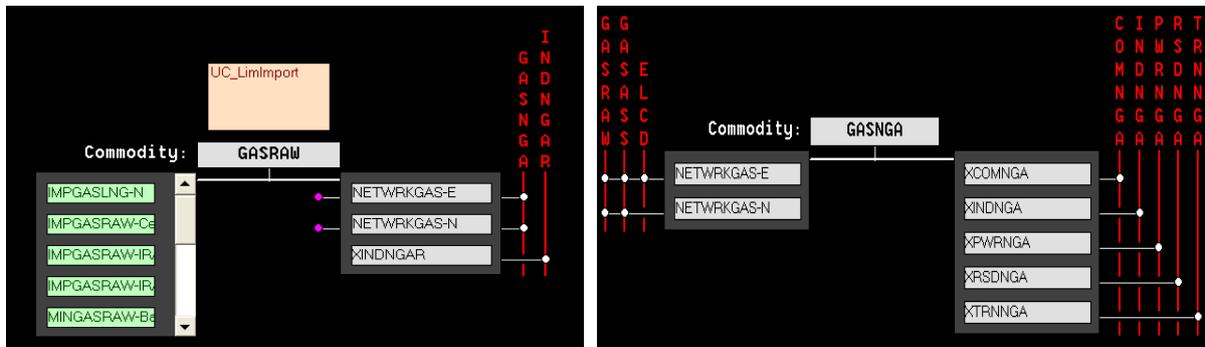
4. How many existing power plants consume only natural gas?

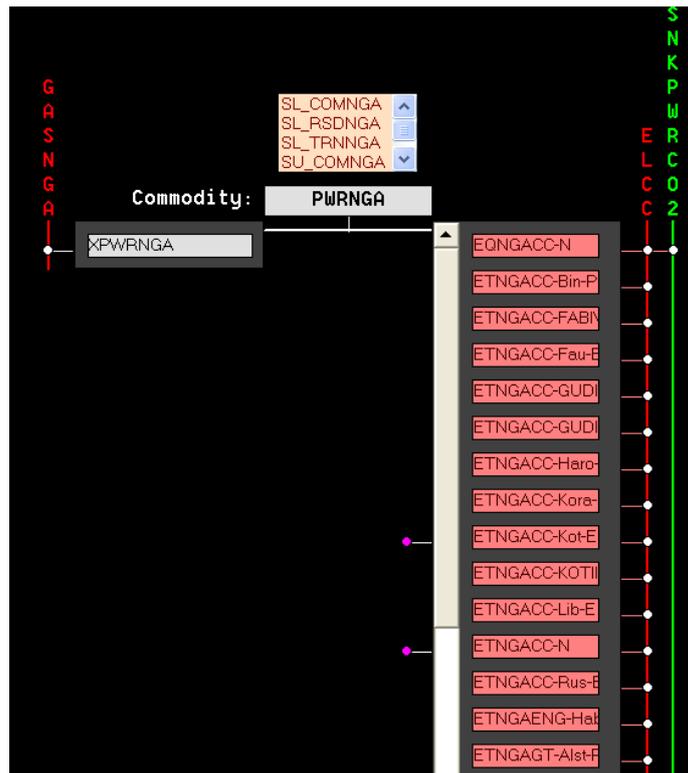
Fifteen (15) as identified using the “search” function in Browse, shown in the figure below. Note that the search criteria used also brings up X processes which needed to be excluded. Another method would be through using the Commodity Master for ELCNGA and identifying process names with just NGA and not ending in N.



- How many different “steps” (including X-processes) does natural gas go through before it is consumed in power plants?

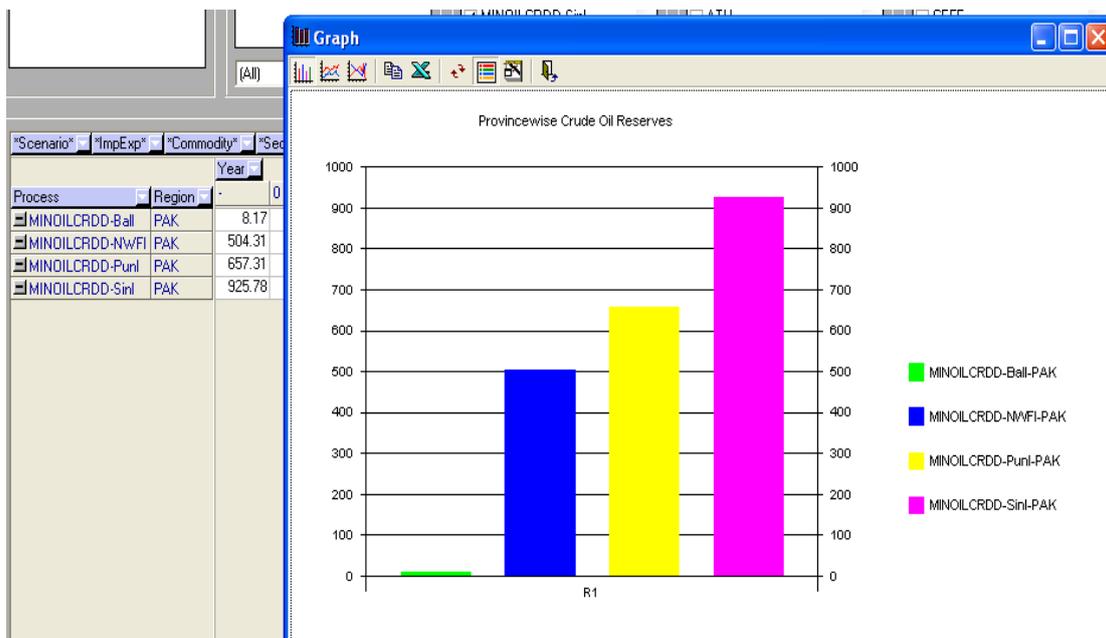
Three “steps” or processes: extraction, shown by the IMP and MIN processes producing GASRAW; the pipeline network processes, which produce GASNGA; and the sector distribution processes (X-<sector>NGA), producing the sector-based NGA commodities. This can be examined via RES or Commodity/Process Master. (See RES example below - click on the commodity to cascade to the next one).





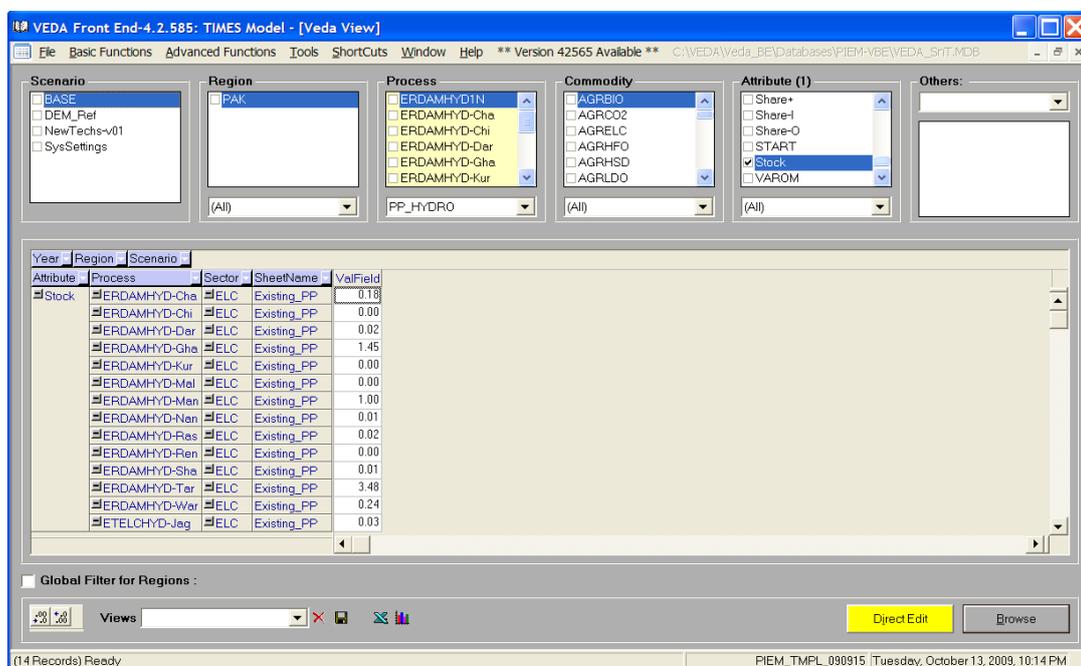
4. Pak-IEM Data Queries

- Which province has the most oil reserves? {Try to draw a bar chart!}
Sindh (at 926 PJ) - see figure below.



- How many existing hydropower plants are there? {Numerous ways to find out.} What is their total installed capacity? {Try using Excel to total the capacity!}

There are 14 existing plants, totaling 6.46 GW. Use the PP_HYDRO set (as shown below) to limit the selection list to hydro plants and select the Stock attribute under the Attributes qualifier to see all the base year values. One can then use a right click or [F7] to Copy then paste the data to a spreadsheet, or export the data to a spreadsheet and calculate the sum.



Pagefields: REGION: PAK; *SCENARIO*: BASE, NewTechs-v01; *OTHIND*:-, _CommGrp_MISSINC

Process	Attribute	Commodi	BD	TS	Sector	Curr	SheetNam	2006 (ValFi
ERDAMHY	Stock	-	-	-	ELC	-	Existing_P	0.18
ERDAMHY	Stock	-	-	-	ELC	-	Existing_P	0.00
ERDAMHY	Stock	-	-	-	ELC	-	Existing_P	0.02
ERDAMHY	Stock	-	-	-	ELC	-	Existing_P	1.45
ERDAMHY	Stock	-	-	-	ELC	-	Existing_P	0.00
ERDAMHY	Stock	-	-	-	ELC	-	Existing_P	0.00
ERDAMHY	Stock	-	-	-	ELC	-	Existing_P	1.00
ERDAMHY	Stock	-	-	-	ELC	-	Existing_P	0.01
ERDAMHY	Stock	-	-	-	ELC	-	Existing_P	0.02
ERDAMHY	Stock	-	-	-	ELC	-	Existing_P	0.00
ERDAMHY	Stock	-	-	-	ELC	-	Existing_P	0.01
ERDAMHY	Stock	-	-	-	ELC	-	Existing_P	3.48
ERDAMHY	Stock	-	-	-	ELC	-	Existing_P	0.24
ETELCHYD	Stock	-	-	-	ELC	-	Existing_P	0.03
								6.46

- How many cars are in the in the base year model?

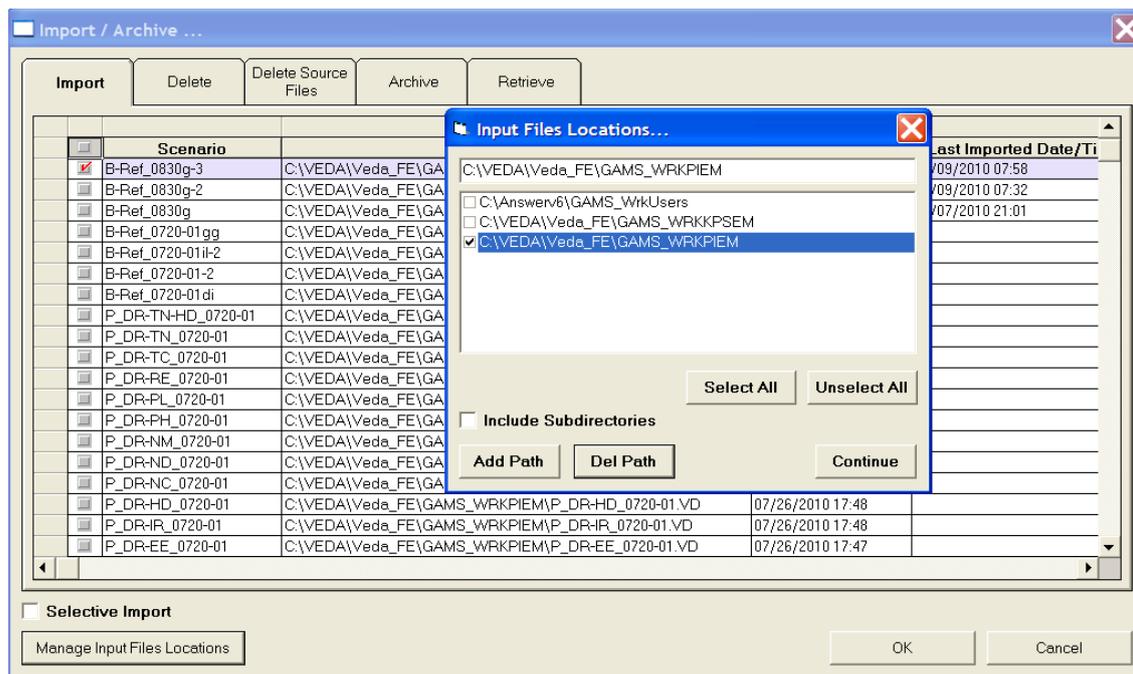
There are 1,872,215 cars. This done in Browse by selecting the Attribute Stock, selecting the process set TCARS and setting the process set filter to exclude any short name containing “-N”. The resulting table can be exported to Excel and the stock values summed.

Pagefields: REGION: PAK; SCENARIO: BASE;					
Attribute	Process	Sector	SheetName\Year	2006 (ValField)	
Stock	TCAGSL1E	TRN	Transportation	255.70	
Stock	TCAGSLCN	TRN	Transportation	1342.42	
Stock	TCAHSD1E	TRN	Transportation	84.11	
Stock	TCAHSD2E	TRN	Transportation	189.99	
				1872.22	Thousand

5. Tools for Examining Results

1. How do you bring the results into VEDA-BE?

Press [F7], or hit the red book icon up top, or select “Results” in the toolbar, then “Import/Archive....”. Make sure that the correct path is set via the “Manage Input Files Locations” button; this should point to the GAMS_WrkPIEM (or GAMS_WrkTIMES) folder where the model results are located. The figure below shows the Import/Archive window and model run listing, along with the File Location list.

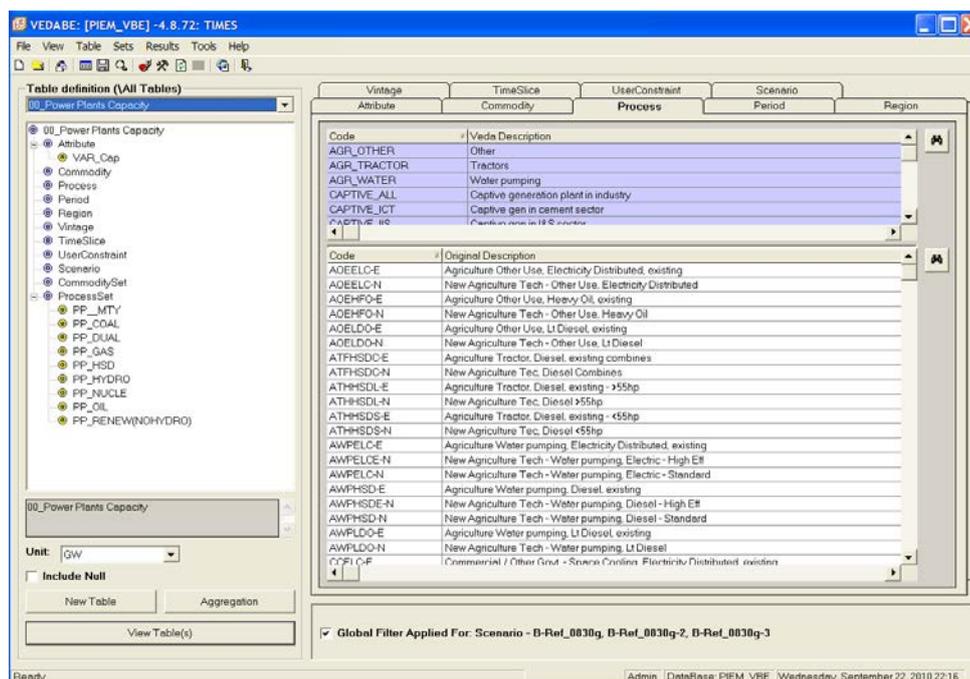


2. What are the key features available in VBE for controlling how results are examined?

Tables and Sets.

3. How is the main VBE form apportioned?

The left shows the current table definition and the right the individual tabs comprising the results data component indexes and their associated lists.



4. What do the tabs on the right correspond to?

The Attribute tab identifies the various result attributes from a model run. The Scenarios tab lists all the model runs currently contained in the VBE database, while the rest of the tabs correspond to the indexes into the various model components, e.g., commodities, processes, etc.

5. What is on the top half of the Process tab?

Process sets, where those in white are the TIMES standard sets, while those shaded are user created.

6. What three ways can you see the “rule” associated with a set?

Place the cursor over the set name, right click on the set name and select Edit/View set, or select Sets/Edit Sets from the menu and navigate in the drop down bar to the specific set to view. [Make sure that you first select Process or Commodity up top in the Set selection form.]

7. How can you tell what table a process set is used in?

Right click on the set name, and select “Used In Tables.”

8. Global Filters

a) What is the purpose of the Global Filter?

This enables the user to limit the results to just those selected without having to move said elements into the table definition.

b) What 2 ways can you select elements for a Global Filter?

Press Ctrl-click on an element to add/remove an element from the global filter, or right click on the element list and select “Global Filter” to pick the desired elements

c) For what tab do you most often use Global Filters?

Scenario.

d) How can you tell if a Global Filter is active?

A ticked text box will show at the bottom of the VBE main form indicating what is included in the Global Filter.

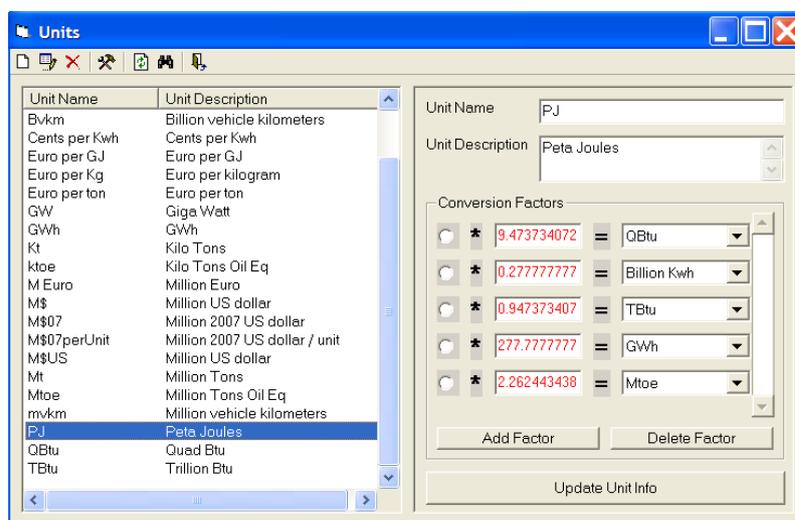


e) How do you turn it off, temporarily?

Un-check the tick box.

9. How do you set the units for a table? How do you convert them to some other compatible unit?

Below the Table Definition window, there is a “Unit” selection box, where units can be selected from a drop down list. Use the Tools/Units manager to enter alternate units and provide the various conversion factors from other units.

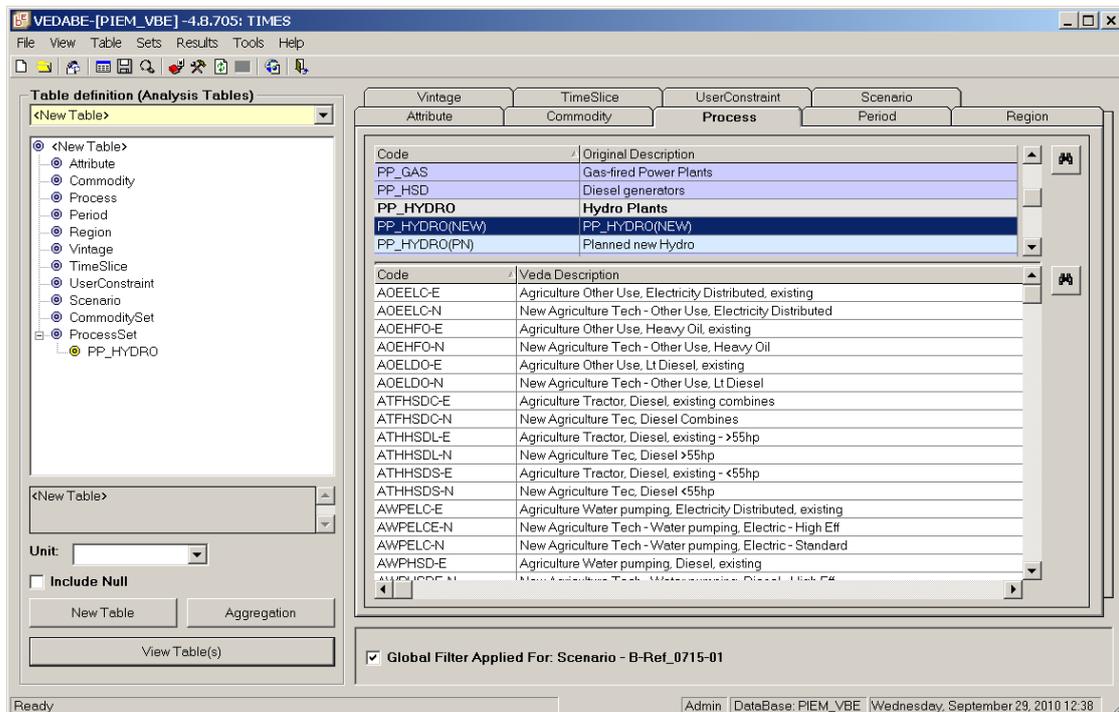
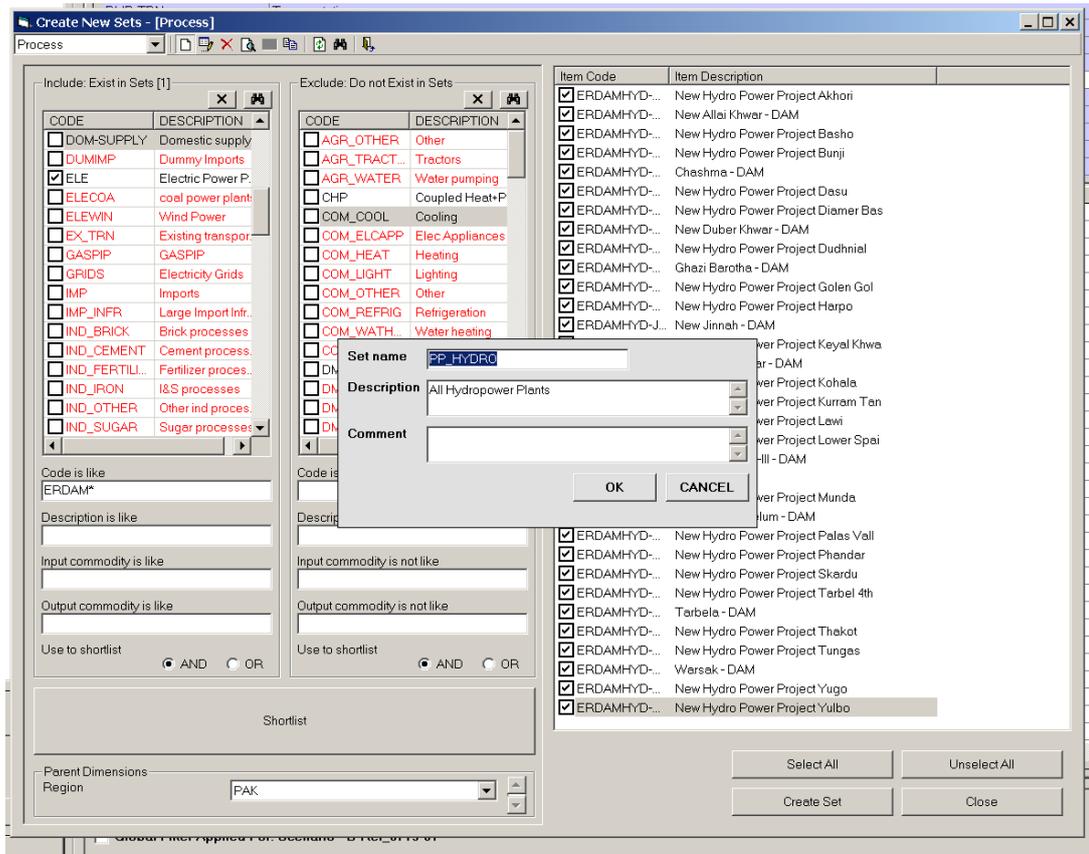


10. Create a new Process Set comprising all the Hydro power plants. Use it to create a new table with all the data associated with just those plants.

Navigate to Sets/New (or press F6). Then select “Process” in the drop down box at the top of the window. In the set definition box, put ERDAM* in “Code is Like” or ELCHYD for the input commodity. Then click on Shortlist to see the qualifying elements, and if correct click “Create set” at the bottom right of the screen, which will bring up a box for entering the name and description of the new process.

To create a new table with this set, select New table under Table Definitions, go to the Process tab and double click on the new set (PP_HYDRO (or PP_HYDRO2 if it already exists)), and click View Table. That will open a box where you can enter a name for the

table. Once in the cube view, the table layout can be arranged to the format needed and that table layout saved.



Process	Commodity	Attribute	2007	2010	2014	2017	2020	2023	2026	2030	
ERDAMHYD-Akhor-N	-	PAR_CapUP	~	~	~	~	~	~	0.60	0.60	
		VAR_NcapM	~	~	~	~	~	~	3,449.46	3,113.29	3,058.82
		Cost_Act	~	~	3.08	3.08	3.08	3.08	3.08	3.08	3.08
		Cost_Form	~	~	6.44	6.44	6.44	6.44	6.44	6.44	6.44
		Cost_Inv	~	~	6.69	6.69	6.69	6.69	6.69	6.69	6.69
		Cost_Salv	15.28	~	~	~	~	~	~	~	~
		VAR_Act	~	~	2.15	2.15	2.15	2.15	2.15	2.15	2.15
		VAR_Cap	~	~	0.12	0.12	0.12	0.12	0.12	0.12	0.12
		VAR_Ncap	~	~	0.12	0.00	0.00	0.00	0.00	0.00	0.00
		VAR_NcapM	~	~	-3,501.12	1,601.39	1,601.39	1,601.39	1,601.39	1,601.39	1,601.39
ERDAMHYD-Akhor-N	-	ELOC VAR_FOut	~	~	2.15	2.15	2.15	2.15	2.15	2.15	
		PWRHYD VAR_FIn	~	~	6.31	6.31	6.31	6.31	6.31	6.31	
ERDAMHYD-Basho-N	-	Cost_Act	~	~	0.71	0.71	0.71	0.71	0.71	0.71	
		Cost_Form	~	~	1.49	1.49	1.49	1.49	1.49	1.49	
		Cost_Inv	~	~	3.02	3.02	3.02	3.02	3.02	3.02	
		Cost_Salv	6.90	~	~	~	~	~	~	~	
		PAR_CapUP	~	~	0.03	0.03	0.03	0.03	0.03	0.03	
		VAR_Act	~	~	0.50	0.50	0.50	0.50	0.50	0.50	
		VAR_Cap	~	~	0.03	0.03	0.03	0.03	0.03	0.03	
		VAR_Ncap	~	~	0.03	~	~	~	~	~	
		VAR_NcapM	~	~	~	841.76	~	75.56	~	~	
		ELOC VAR_FOut	~	~	0.50	0.50	0.50	0.50	0.50	0.50	
ERDAMHYD-Basho-N	-	PWRHYD VAR_FIn	~	~	1.46	1.46	1.46	1.46	1.46	1.46	
		Cost_Act	~	~	~	~	~	~	114.54	178.18	178.18
ERDAMHYD-Bunji-N	-	Cost_Form	~	~	~	~	~	~	239.36	372.33	372.33
		Cost_Inv	~	~	~	~	~	~	379.35	590.10	590.10
		Cost_Salv	1,448.19	~	~	~	~	~	~	~	~
		PAR_CapUP	~	~	~	~	~	~	7.00	7.00	7.00

11. How can you easily view the flows in/out of a process, and cascade through the RES? {2 ways – new}

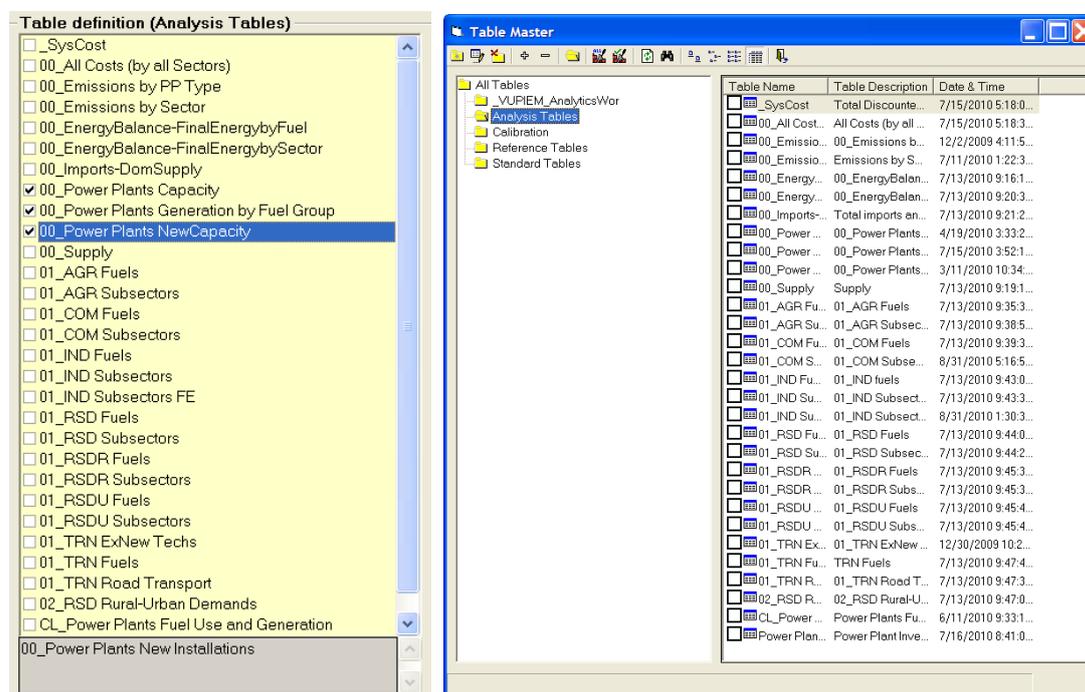
Right-mouse click and select ExRES on the Process/Commodity of interest. This can be done directly on the Process or Commodity tab for individual items or sets. It can also be done in the cube view of a table or via the View/Reference Energy System menu. Note that the ExRES will show either all the data associated with the qualifying items or just the in/out flows depending upon the state of the  button (shown here to display in/out flows only).

Scenario	Region	Attribute	Commodity	Period
PIEM_090915	PAK	VAR_FIn	AGRHS	77.95
		VAR_FOut	ATF	12.79
			ATU	2.81

12. How can you retrieve multiple tables via a single request {2-ways – new}

The first way is via View/Execution Mode/Batch Mode (or Ctrl-B, where Ctrl-I will switch back to Interactive single table selection mode) and check the desired table (more than two are possible) and click View Table. The second method is to use the Table/Table

Master and select the desired node of the tree, click the desired tables, and click either  to view all or selected tables in the folder. Note that the Table Master will automatically export the tables to an Excel file.



6. Calibration (2007) Run Results

1. What is the total amount of domestic supply (including renewables)?

Select and view the Supply – Domestic table, with the Global Filter set to the Reference scenario. put the cursor on the Scenario, and via right-mouse either request Totals or hide Details. The value is 2,554.09 PJ.

2. Which refinery produced the most OILLDO?

Select and view the 00_Refinery Output table, and bring down the processes. Right-click in the Commodity column and select Display/Code only to see the OILLDO commodity. Click on the Commodity selection menu and use control click to unselect all items and then click to select only OILLDO. Scan the 2007 column of output values to identify the maximum value (0.12 PJ) is from the National Refinery, as shown in the figure below. [Remember, **don't** save the reconfigured table as it's an update table for the Analytics workbook!]

Original Units: PJ Active Unit Mtoe Data values filter:

Scenario	Process	Commodity	Period							
			2007	2010	2014	2017	2020	2023	2026	2030
B-Ref_0715-01	PREF-Atto-E	OILLDO	0.00	0.04	~	~	0.06	0.04	0.04	0.04
	Total		0.00	0.04	~	~	0.06	0.04	0.04	0.04
	PREF-Bosi-E	OILLDO	0.00	~	~	~	0.04	0.02	0.02	0.02
	Total		0.00	~	~	~	0.04	0.02	0.02	0.02
	PREF-Bosi-PN	OILLDO	~	~	~	0.01	0.03	~	0.03	0.03
	Total		~	~	~	0.01	0.03	~	0.03	0.03
	PREF-Khal-PN	OILLDO	~	~	~	~	0.00	~	~	~
	Total		~	~	~	~	0.00	~	~	~
	PREF-Nati-E	OILLDO	0.12	0.06	0.07	0.12	0.00	0.02	0.01	0.14
	Total		0.12	0.06	0.07	0.12	0.00	0.02	0.01	0.14
	PREF-New-N	OILLDO	~	~	~	~	~	~	~	1.85
	Total		~	~	~	~	~	~	~	1.85
	PREF-Pak-E	OILLDO	~	~	0.06	~	~	0.05	~	0.05
	Total		~	~	0.06	~	~	0.05	~	0.05
PREF-PakA-E	OILLDO	0.04	~	~	~	~	~	~	0.13	
Total		0.04	~	~	~	~	~	~	0.13	
PREF-Tran-PN	OILLDO	~	~	~	~	~	~	0.03	0.03	
Total		~	~	~	~	~	~	0.03	0.03	

Global Filter Applied For: Scenario - B-Ref_0715-01

(474 Records) Ready

3. How much natural gas is consumed in the power sector?

Select and view the Story - Power Plants table, Click on the Commodity pull-down list and use Control-click to select only Natural Gas. Right click in the Process column to request a Total for all processes. The total is 374.69 PJ, as shown in the figure below.

Original Units: PJ Active Unit PJ Data values filter:

Scenario	Process	Attribute	Commodity	Period							
				2007	2010	2014	2017	2020	2023	2026	2030
B-Ref_0830g	ETNGASTM-FABV-E	VAR_Fin	Natural Gas	1.52	2.75	2.75	~	~	~	~	~
	ETNGASTM-GUDIII-E	VAR_Fin	Natural Gas	9.86	9.86	9.86	~	~	~	~	~
	ETNGASTM-GUDIV-E	VAR_Fin	Natural Gas	15.98	15.98	15.98	~	~	~	~	~
	ETNGASTM-JAMI-E	VAR_Fin	Natural Gas	7.54	7.54	7.54	7.54	7.54	7.54	~	~
	ETNGASTM-JAMI-E	VAR_Fin	Natural Gas	24.53	24.53	24.53	24.53	24.53	24.53	~	~
	ETNGASTM-Korangi-E	VAR_Fin	Natural Gas	11.96	11.96	11.96	11.96	11.96	11.96	11.96	11.96
	ETNGASTM-M-GARI-E	VAR_Fin	Natural Gas	6.05	6.05	6.05	6.05	6.05	6.05	3.02	~
	ETNGASTM-M-GARI-E	VAR_Fin	Natural Gas	3.49	3.49	3.49	3.49	3.49	3.49	1.75	~
	ETNGASTM-M-GARIII-E	VAR_Fin	Natural Gas	7.85	7.85	7.85	7.85	7.85	7.85	3.92	~
	ETNGASTM-MULVII-E	VAR_Fin	Natural Gas	~	2.94	~	~	~	~	~	~
Total				374.69	381.89	474.04	385.16	367.62	326.72	285.96	223.91

Global Filter Applied For: Scenario - B-Ref_0830g

(12928 Records) Ready

4. What is the total installed hydro capacity?

Select and view the 00_Power Plants Capacity table. The answer (6.47GW) is immediately displayed in the table.

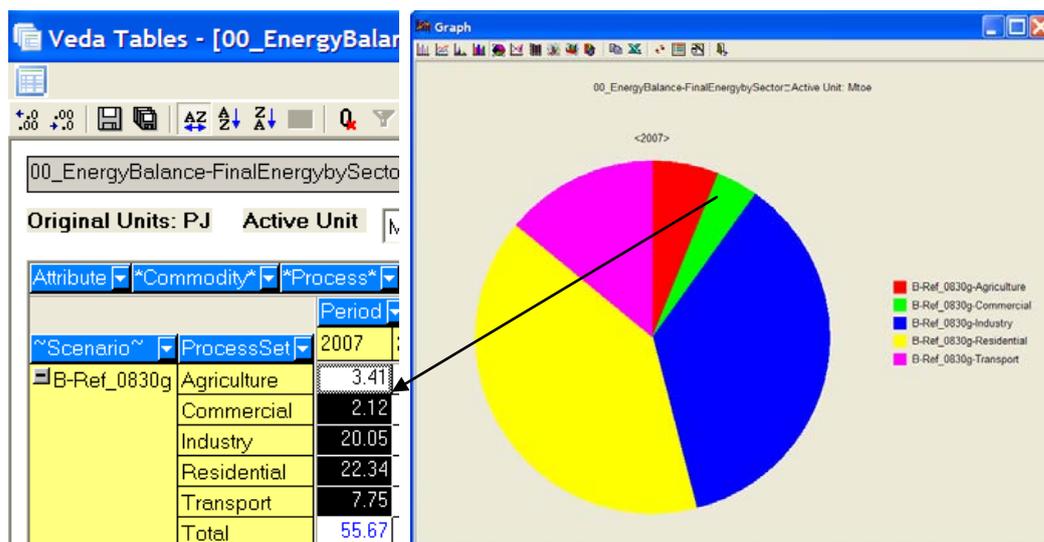
5. How much electricity is generated from hydro plants in the summer day timeslice?

Select and view the 00_Power Plants Generation by Fuel Group table and pull down the Timeslice dimension to the right of the Period header as shown in the figure below. The answer, 18.89 billion kWh, is displayed.

Scenario	ProcessSet	I	ID	IN	IP	IS	S	SD	SN	SP	SS	W	WD	WN	WP	WS	I	
B-Ref_0830g	Coal-fired Power Plants	0.07	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~	~
	Dual-fired Power Plants	~	3.15	2.05	0.92	1.36	~	5.26	3.05	0.86	1.61	~	3.84	2.48	0.81	1.90	~	
	Gas-fired Power Plants	~	2.07	0.80	0.33	0.56	~	3.18	2.03	0.45	0.94	~	2.43	1.49	0.32	0.87	~	
	Hydro Plants	7.56	~	~	~	~	18.89	~	~	~	~	5.30	~	~	~	~	~	
	Nuclear Power Plants	0.51	~	~	~	~	0.89	~	~	~	~	0.88	~	~	~	~	~	
	Oil-fired Power Plants	~	1.21	1.30	0.32	0.83	~	3.49	2.38	0.86	1.79	~	2.28	0.91	0.69	1.09	~	
	Renewables (non-Hydro)	~	~	~	~	~	~	0.00	~	~	~	~	~	~	~	~	~	
	Total	8.14	6.44	4.15	1.57	2.75	19.78	11.93	7.46	2.17	4.34	6.32	8.55	4.88	1.81	3.86	~	

6. What sector is consuming the least amount energy, and what is the level?

Select and view the 00_EnergyBalance-FinalEnergybySector table. A scan of the 2007 column shows that the Commercial sector at 2.12Mtoe is the smallest sector in the base year. A Pie chart can be created by selecting the sector values as shown, clicking [Pie Chart Icon] to open the Graphing tool, and selecting @D Pie from the Picture menu at the top of the tool window.



7. How much gasoline is consumed in the transportation sector?

Using the same 00_EnergyBalance-FinalEnergybySector table, pull down the Commodity tab to the right of the Process Set tab. Scroll down to the Transportation sector, and the value for OILGSL (1.20Mtoe) is displayed.

8. What is the total energy consumption in industry?

Using the same 00_EnergyBalance-FinalEnergybySector table, pull down the Commodity tab to the right of the Process Set tab. Scroll down to the Industry sector and right click in the commodity column to select Total, which will sum all the energy carriers used in each sector. The value for Industry is 20.05Mtoe.

9. How much electricity is consumed in the commercial sector?

Using the same 00_EnergyBalance-FinalEnergybySector table, with the Commodity tab pulled down to the right of the Process Set tab, the value for ELCD is 0.8Mtoe.

10. What is the price of natural gas in the pipeline, and delivered to the commercial customers?

Select and view the Marginals – All Commodities table and on the Commodity pull-down list use control-click to unselect all commodities, and then select only GASNGA and COMNGA. COMNGA has a single value (17.77 \$/GJ), but GASNGA has seasonal values (all currently 5.91 \$/GJ).

Veda Tables - [Marginals - All Commodities]

Marginals - All Commodities

Original Units: \$ per GJ Active Unit \$ per GJ Data values filter: /

Attribute	Region	Period	2007	2010	2014	2017	2020	2023	2026	2030
Scenario	Commodity	TimeSlice								
B-Ref_0715-01	COMNGA	W	17.77	28.64	38.72	44.14	49.22	152.57	290.29	604.42
	GASNGA	I	5.91	7.11	9.05	10.62	12.37	14.28	16.98	20.85
		S	5.91	7.11	9.05	10.62	12.37	14.28	16.98	20.85
		W	5.91	7.11	9.05	10.62	12.37	14.28	16.98	20.85

Global Filter Applied For: Scenario - B-Ref_0715-01

(3304 Records) Ready

11. What is the total amount of domestic oil produced?

Select and view the Supply – Domestic table. Right click in the Process column to get a Total for all provincial supplies of 132.50 PJ.

12. What is the total amount of imported oil products?

Select and view the Supply – Imports table. From the Commodity pull-down list, multi-select the petroleum products and then right click in the Commodity column to request Total. The result, as shown below, is 383.41 PJ.

Supply - Imports

Original Units: PJ Active Unit PJ

Attribute	Region	*Vintage*	*TimeSlice*	ProcessSet	*Process	Period	Data
~Scenario~					-Commodity-	2007	20
B-Ref_0830g					Diesel		210.49
					Heavy Oil		171.84
					LPG		1.07
					Total		383.41

7. Reference Scenario Model Results

1. What is the total cost of the Pakistan energy system over the 2040 modeling horizon?

[\$964,158.28Million]

Veda Tables - [SysCost]

Total Discounted System Cost (OBJ)

Original Units: M\$07 Active Unit M\$07 Data values filter:

Attribute	Value
Scenario PV	
B-Ref_1123	964,158.28

Global Filter Applied For: Scenario - B-Ref_1123

(Records) Ready

2. By how much does the share of imports in total supply change in 2030 compared with 2007?

[9.11% more imports]

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1																				
2																				
3																				
4																				
5		Table Name: 00_Imports-DomSupply																		
6		Active Unit: Mtoe																		
7		Scenario	ProcessSetDesc:Period	2007	2008	2010	2011	2012	2013	2014	2015	2016	2020	2025	2030	2035	2040	share 2007;share 2030		
8		B-Ref_1123	Domestic supply	57.87	56.39	56.69	56.56	59.49	61.40	63.12	63.88	65.58	73.44	95.37	120.89	141.55	178.83			
9		B-Ref_1123	Imports	20.72	19.81	20.86	24.26	24.90	29.66	29.90	30.19	31.90	36.84	45.71	66.48	94.53	119.28			
10		B-Ref_1123	Total	78.60	76.20	77.55	80.83	84.38	91.06	93.01	94.06	97.47	110.28	141.08	187.36	236.08	297.92			
11																	26.37%	35.48%		
12																	change	9.11%		
13																				
14																				
15																				
16																				

3. Which supply option increases the most (ktoe) between 2007-2030?

[coal, going from 4.43Mtoe to 44.80Mtoe]

Scenario	CommoditySet	2007	2008	2010	2011	2012	2013	2014	2015	2016	2020	2025	2030	2035	2040
B-Ref_1123	COAL	4.43	4.60	4.95	5.06	5.25	5.56	5.85	6.12	6.59	12.24	26.83	44.80	66.85	93.48
	Hydroelectric	7.63	6.87	7.00	7.09	7.52	7.66	8.80	8.87	10.85	15.01	24.03	31.30	38.49	46.07
	Natural Gas	29.32	29.42	28.88	30.11	32.30	37.96	38.19	38.61	38.70	37.37	28.45	28.16	31.72	41.27
	Nuclear	0.55	0.55	0.55	1.13	1.13	1.08	1.08	1.08	1.08	3.41	14.06	22.94	31.83	40.72
	Oil & Products	20.70	19.78	20.79	21.85	22.30	22.62	22.74	24.13	27.49	32.95	38.59	45.14	53.39	
	Renewables (excl. hydro)	15.89	14.90	15.29	15.52	15.80	16.08	16.35	16.57	16.04	14.65	14.51	21.28	21.71	22.60
	Total	78.51	76.12	77.47	80.75	84.30	90.97	92.93	93.98	97.39	110.17	140.82	187.07	235.74	297.53

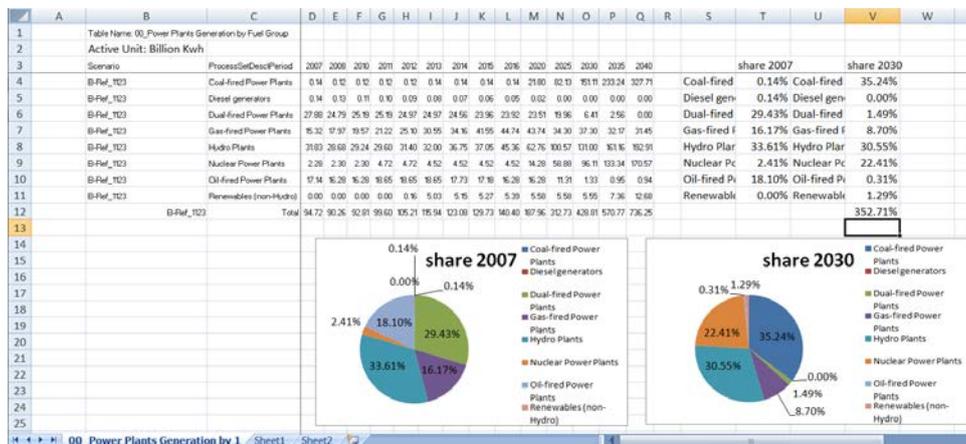
4. What is the total amount of new power plants built over the entire planning horizon? In which period prior to 2030 is the most built, and in said period what particular type of power plants leads the new builds?

[135.46GW, 2020, 10.5GW coal IGCC]

Scenario	ProcessSet	2008	2010	2011	2012	2013	2014	2015	2016	2020	2025	2030	2035	2040	Total
B-Ref_1123	Coal-fired Power Plants	~	~	~	~	~	~	~	~	10.50	10.00	12.50	12.50	12.50	58.00
	Gas-fired Power Plants	0.74	0.68	0.70	~	0.88	1.05	1.00	1.19	1.50	0.82	~	~	~	8.55
	Hydro Plants	0.08	~	0.07	0.37	0.12	0.96	0.06	2.12	9.49	6.18	6.07	6.33	7.50	39.35
	Nuclear Power Plants	~	~	0.33	~	~	~	~	~	3.30	5.00	5.00	5.00	5.00	23.63
	Oil-fired Power Plants	0.19	0.48	1.56	0.43	~	~	~	~	~	~	~	~	~	2.65
	Renewables (non-Hydro)	~	~	~	0.05	0.79	0.02	0.02	0.04	0.01	~	~	~	0.75	1.59
Total		1.00	1.16	2.66	0.84	1.80	2.03	1.08	3.35	24.81	21.99	23.57	24.58	26.59	135.46

5. How much (percent) does electricity generation increase by 2030, and explain the shift in electricity generation mix between 2007 and 2030?

[Total generation increases 353%, with a major shift to coal and nuclear at the expense of oil.]



6. By what year will Pakistan need more than 15Mtoe of additional product output from a new refinery, and in said year what product dominated production?

[2030, diesel]

Veda Tables - [00_Refinery Products]

Original Units: PJ Active Unit: Mtoe Data values filter:

Scenario	Commodity	2007	2008	2010	2011	2012	2013	2014	2015	2016	2020	2025	2030	2035	2040
B-Ref_1123	Av. Fuel	1.25	0.75	0.81	0.81	0.82	0.86	0.90	0.95	1.01	1.27	2.38	3.30	3.80	4.31
	Diesel	3.55	4.40	4.68	4.68	4.68	4.94	5.43	5.43	7.16	8.50	10.75	12.91	15.16	17.40
	Gasoline	1.34	1.37	1.53	1.52	1.46	1.49	1.58	1.65	1.84	2.80	4.05	4.95	5.91	6.86
	Heavy Oil	3.21	4.19	4.43	4.41	4.41	4.61	5.17	5.10	6.36	6.48	5.39	3.73	4.01	4.29
	Kerosene	0.21	0.19	0.43	0.45	0.45	0.49	0.55	0.55	0.64	0.64	1.60	2.04	2.49	2.94
	LPG	0.23	0.42	0.45	0.45	0.45	0.48	0.54	0.54	0.88	1.15	1.60	2.04	2.49	2.94
	Lt Diesel	0.17	0.12	0.14	0.15	0.16	0.16	0.15	0.15	0.15	0.15	0.13	2.05	2.50	2.95
	Naptha	1.05	1.13	0.70	0.69	0.73	0.71	0.59	0.55	1.19	1.59	2.29	2.53	2.81	3.09
	Total	11.02	12.56	13.16	13.16	13.16	13.74	14.92	14.92	19.23	22.58	28.20	33.54	39.16	44.79

Global Filter Applied For: Scenario - B-Ref_1123

(819 Records) Ready

7. Which demand sector has the biggest increase between 2007-2030 in ktoe and in percent of total?

[Industry 24.92Mtoe, Residential up by 4.64% of total demand]

Scenario	ProcessSetDesc/Period	2011	2012	2013	2014	2015	2016	2020	2025	2030	2035	2040	increase 2030	share 2007	share 2030	diff
													ktoe	%	%	%
B-Ref_1123	Agriculture	3.48	3.58	3.68	3.77	3.89	4.22	5.10	5.77	6.87	8.43		2.40	4.30%	5.08%	0.78%
B-Ref_1123	Commercial	1.89	2.06	2.22	2.31	2.30	2.54	3.17	3.94	4.71	5.64	6.71	2.63	4.71%	4.14%	-0.57%
B-Ref_1123	Industry	20.60	21.44	22.42	23.08	23.76	24.88	28.51	32.47	45.05	61.46	84.24	24.92	44.70%	39.64%	-5.06%
B-Ref_1123	Residential	22.49	23.75	24.52	24.91	25.85	25.80	27.09	29.39	38.91	44.11	50.72	16.51	29.61%	34.25%	4.64%
B-Ref_1123	Transport	8.62	8.77	9.07	9.36	9.65	10.14	12.20	15.35	19.20	24.30	31.68	11.44	20.53%	16.89%	-3.63%
	Total	57.09	59.61	61.93	63.43	65.21	67.25	75.19	88.25	113.63	142.39	181.79				

8. Which demand sector consumes the most electricity in 2030 (BKwh), and what percentage of the total does it require?

[Residential with 182BKwh accounting for 50.52% of total electricity consumption]

Electricity to Demand Sectors

Original Units: PJ Active Unit Billion Kwh Data values filter:

Scenario	Attribute	Commodity	2007	2008	2010	2011	2012	2013	2014	2015	2016	2020	2025	2030	2035	2040
B-Ref_1123	VAR_FOut	AGRELC	7.91	7.24	7.49	8.16	9.11	10.12	10.53	10.93	11.35	13.07	20.10	25.74	34.64	44.57
		COMELC	9.76	8.73	7.43	8.70	9.95	11.10	11.58	12.00	12.86	16.09	20.19	24.54	29.95	36.00
		INDEL	21.45	20.12	23.39	22.41	20.00	22.55	25.47	27.99	32.22	52.34	89.10	128.48	179.68	245.05
		RSDEL	33.86	33.46	35.90	39.63	44.76	49.62	52.03	54.50	58.17	74.18	132.62	182.63	240.38	297.54
		TRNEL	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.05	0.12	1.76	2.72
		Total	72.98	69.56	74.22	78.91	83.84	93.40	99.62	105.44	114.63	155.71	262.06	361.51	486.40	625.87

Global Filter Applied For: Scenario - B-Ref_1123

(1619 Records) Ready

9. In which period is total gas consumption the lowest, and what is that value?
 [2025 at 25.68Mtoe]

00_Gas Consumption (All Sectors)

Original Units: PJ Active Unit Mtoe Data values filter:

Scenario	ProcessSet	2007	2008	2010	2011	2012	2013	2014	2015	2016	2020	2025	2030	2035	2040
B-Ref_1123	Commercial	0.73	0.90	0.83	0.86	0.89	0.93	0.98	1.02	1.09	1.38	1.72	2.05	2.41	2.89
	Industry	11.29	11.36	10.85	11.39	12.27	12.71	12.79	12.92	13.14	12.97	9.28	11.23	14.78	20.27
	Power Sector	8.50	8.52	8.91	9.27	9.95	14.81	14.96	14.84	14.28	11.60	8.57	7.10	5.05	4.27
	Residential	4.34	4.24	3.98	4.08	4.32	4.42	4.36	4.69	5.04	6.48	4.53	3.02	3.01	4.02
	Transport	1.32	1.25	1.24	1.31	1.42	1.50	1.52	1.55	1.55	1.50	1.58	2.33	3.68	6.06
	Total	26.19	26.28	25.81	26.90	28.85	34.37	34.60	35.00	35.10	33.92	25.68	25.73	28.93	37.51

Global Filter Applied For: Scenario - B-Ref_1123

(246 Records) Ready

10. What is the annual expenditure on the energy system in 2030, and what percentage increase occurs in the resource supply costs by 2030?
 [\$125,735 Million, 293%]

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1																		
2																		
3																		
4																		
5		Table Name: 00_All Costs																
6		Active Unit: M\$07																
7		Scenario	Attribute/Desc/Period	2007	2008	2010	2011	2012	2013	2014	2015	2016	2020	2025	2030	2035	2040	
8		B-Ref_1123	Activity cost (Delivery+VarO&M)	7399.35	9908.70	10737.66	7634.73	4574.73	1492.74	1549.49	1601.11	1697.64	1870.07	2307.69	3183.05	4479.86	6531.15	
9		B-Ref_1123	Fixed O&M costs	2989.20	3229.81	3054.45	3908.48	4077.73	4342.42	4489.78	4626.95	4782.25	6260.29	9403.29	13009.89	17439.38	22882.92	
10		B-Ref_1123	Investment costs (annual)	0.00	1862.37	5429.42	7329.17	9077.93	11294.68	13274.21	15354.85	17697.09	26431.76	38076.84	62601.88	71319.60	94229.74	
11		B-Ref_1123	Resource supply costs (including trade)	14495.74	13960.42	15945.59	18028.21	19680.90	22966.84	24058.20	25383.81	26142.08	33363.90	41874.98	56940.26	79837.37	106961.83	
12		B-Ref_1123	Total	24884.28	28961.31	35667.11	36900.58	37411.29	40096.67	43371.68	46966.73	50319.06	67926.03	91668.80	125735.09	173076.21	230605.65	
13																		
14																		
15																		
16																		

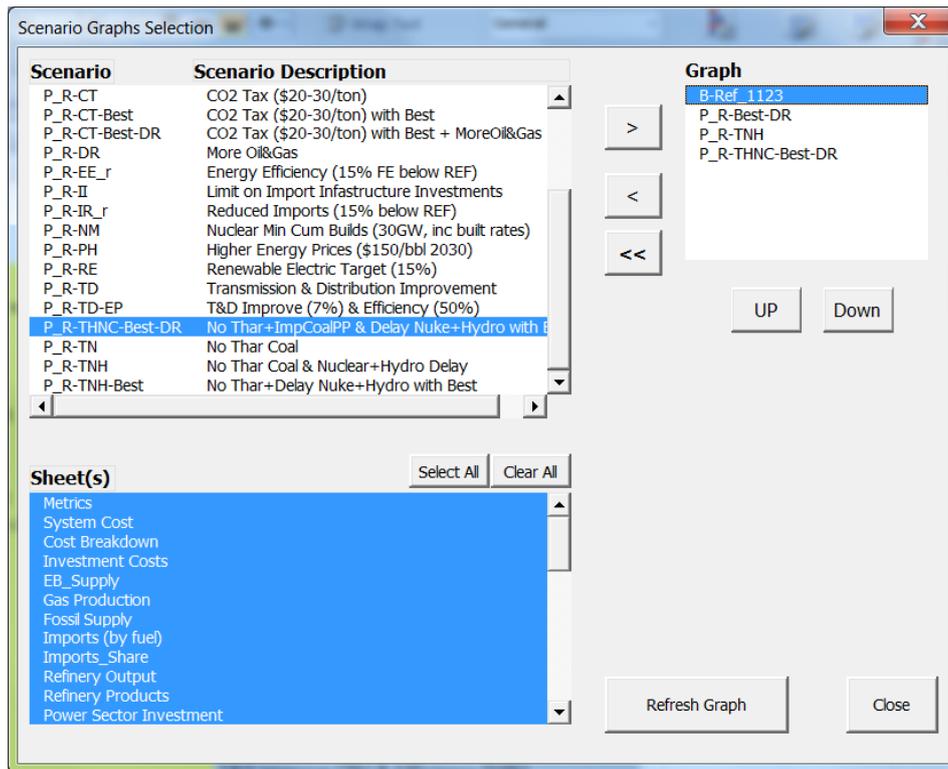
11. What is the purpose of the AU_ELC user constraints, and what do the marginal values tell us?

[to limit the GW of new capacity by fuel type that can be built in a period, where the negative marginal indicates where said constraint is binding and how much the objective function could be reduced if another GW of capacity was permitted in each period.]

Scenario	UserConstraint	2008	2010	2011	2012	2013	2014	2015	2016	2020	2025	2030	2035	2040	
B-Ref_1123	AU_ELC_NCAPH-COA									-339.29	-82.08	-104.41	-129.75	-135.67	-38.49
	AU_ELC_NCAPH-HYD					-186.20				-201.52	-80.25				-8.91
	AU_ELC_NCAPH-NGA		-1,342.22	-897.95	-760.49	-486.64	-270.39								
	AU_ELC_NCAPH-NJC			-1,122.18	-922.53	-879.70	-803.64	-687.47	-273.54	-97.12	-177.85	-171.48	-139.47		
	AU_ELC_NCAPH-WM4													-6.61	-34.95
	AU_ELC_NCAPH-WM5													-8.61	-34.95
	AU_ELC_NCAPH-WM6														-29.90
	SL_AGRADE_ELC			15.64	21.89	25.00	16.71	23.40	19.19	12.38					
	SL_AGRADE_LDO	10.12	10.18								14.34	14.91	16.09	16.73	
	SL_AGRAMP_HSD	31.74	32.39	22.66	21.17	20.50	24.71	22.71	26.59	31.24	42.93	43.30	46.38	1.20	
	SL_AGRAMP_LDO	24.10	24.31	14.20	12.32	11.27	15.06	12.72	15.84	19.10	27.70	24.77	26.55	18.24	
	SL_AGRELC	0.09	22.44								16.89	21.14	20.47	27.06	
	SL_AGRHSD													47.05	
	SL_BMARKET_DSL	3.49	3.72	3.94	4.15	4.36	4.57	4.79	5.10	5.76	6.28	6.72	7.20	7.56	
	SL_COMOOTH_AVG				0.00	0.00				0.00	0.00	6.96	7.46	7.83	
	SL_COMOOTH_CSI		0.00	0.00				0.94	0.00	0.00	13.63	23.84	26.90	27.37	

8. Sensitivity Scenario Model Results

This section relies primarily on the use of Analytics Excel workbook to examine and compare various model results, while reinforcing how to use the workbook. Set up the workbook to compare the four cases shown below (REF, REF-Best+DR, NoTNH, NoTNH-Best+DR) to answer most of the case comparison questions.



11. Which model run has the lowest overall system cost?

[The low demand run, P_DemL with \$775,578Million.]

	A	B	C
1			
2			
3			
4			
5			
6			
7		Scenario	PV
8		P_DemL	775578.6124
9		P_DemM	860346.1076
10		P_R-Best-DR	939969.4651
11		P_R-DR	950564.2719
12		P_R-II	953164.3226
13		P_R-TD-EP	953270.5142
14		P_R-Best	953270.5142
15		P_R-TD	961578.6132
16		P_R-NM	963055.8661
17		P_R-THNC-Best-DR	964093.7776
18		B-Ref_1123	964158.28
19		P_R-CC_r	974617.6493
20		P_R-EE_r	975270.1671
21		P_R-TNH-Best	978608.2577
22		P_R-RE	980125.684
23		P_R-TN	993777.5548
24		P_R-TNH	1007924.539
25		P_R-CT-Best-DR	1008454.744
26		P_R-CT-Best	1022127.042
27		P_R-CT	1037840.796
28		P_R-PH	1038680.782
29		B-Ref_1123-sp	1097941.49
30		P_R-IR_r	1310915.236
31			
32			
33			
34			
35			

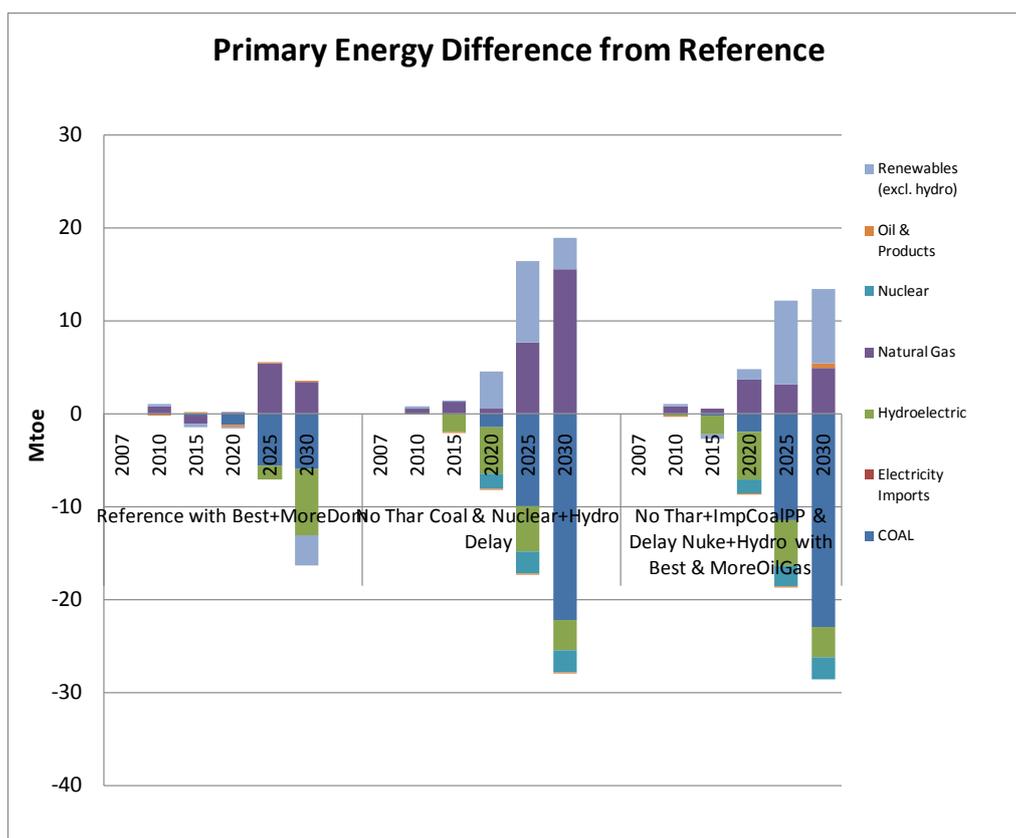
12. What happens to total imports when for the 3 sensitivity runs?

[As shown on the Metrics sheet Best and More Gas reduces overall imports, while limiting Thar and delaying nuclear&hydro naturally raises imports.

Scenario		
Reference	2,110	
Reference with Best+MoreDom	-135	-6.40%
No Thar Coal & Nuclear+Hydro Delay	406	19.23%
No Thar+ImpCoalPP & Delay Nuke+Hydro with Best & MoreOilGas	17	0.78%

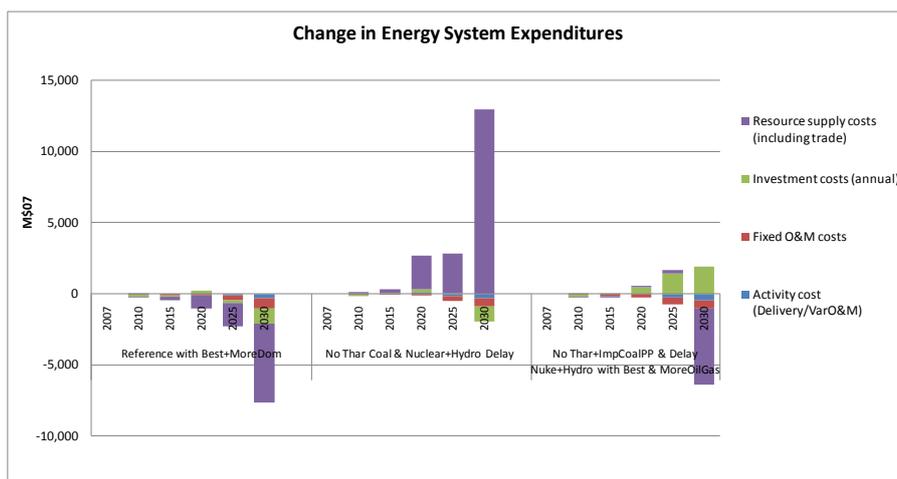
13. Which 2 fuel needs to step in for the no/delay cases, by how much in 2030 in the delay but no Best practices case, and what amount of natural gas is saved under Best practices and what is the additional renewables in 2030?

[Natural gas and renewables, 19Mtoe, 11Mtoe, wind]



14. How much is saved starting in 2030 each year on the expenditure for fuel when following Best practices?

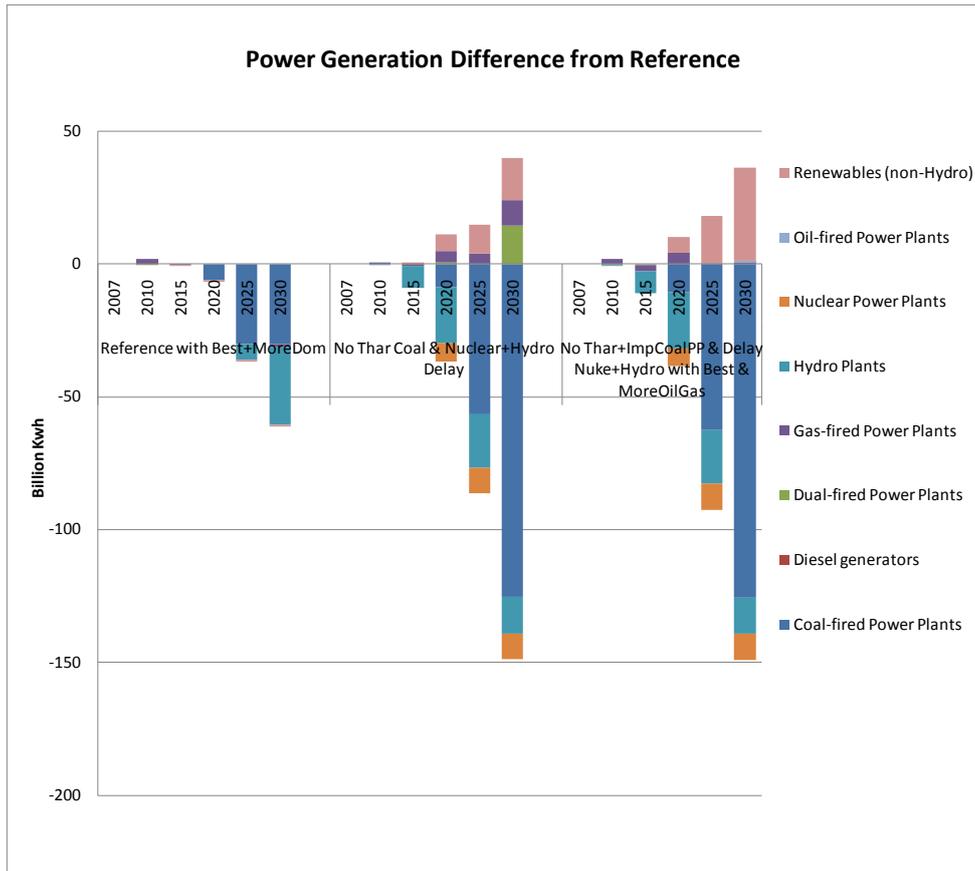
[\$5.55Billion/year]



15. How many GW less new capacity is installed in each of the three alternate scenarios?
 [8.81/18.98/18.65GW less respectively]

Scenario		
Reference	2,110	
Reference with Best+MoreDom	-8.81	-6.51%
No Thar Coal & Nuclear+Hydro Delay	-18.98	-14.01%
No Thar+ImpCoalPP & Delay Nuke+Hydro with Best & MoreOilGas	-18.65	-13.77%

16. How many less GWh of electricity are required per annum under each alternate scenario in 2025?
 [37/72/74GWh less respectively]



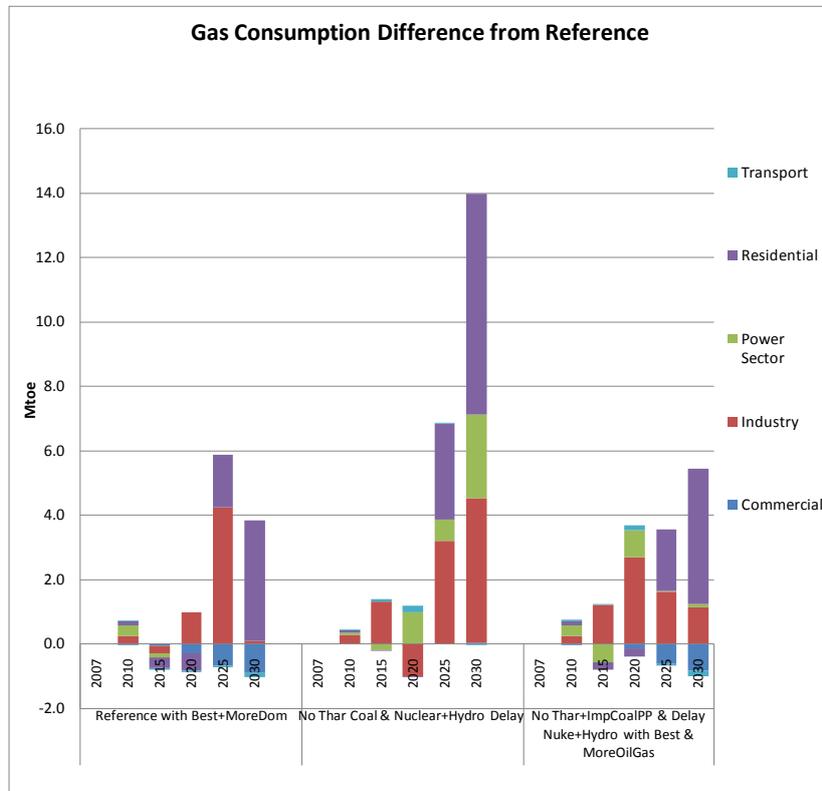
17. Discuss the impact on electricity prices in 2025 for each scenario?

[decreases substantially when no delay (due to Thar) while increases substantially with the delay, but “bite” is lessened when Best employed]

Commodity	Time/Scenario	2007	2008	2010	2011	2012	2013	2014	2015	2016	2020	2025	2030	2035	2040
ELCD	B-Ref_1123	166.70	0.09	20.18	26.41	33.22	37.33	29.65	37.19	33.76	30.00	15.59	19.64	19.01	25.14
	P_R-Best-DR	166.70	1.06	16.83	22.36	28.27	33.78	24.82	29.46	24.80	25.83	15.95	14.78	18.93	19.39
	P_R-TNH	166.70	0.84	20.07	29.50	33.97	35.27	34.96	30.91	37.60	38.06	34.04	40.21	40.53	49.84
	P_R-TNH+Best	166.70	0.36	18.73	26.62	32.01	31.88	33.24	27.31	34.09	34.39	25.78	29.35	32.69	42.43
IN	B-Ref_1123	166.70	0.09	20.18	26.41	33.22	37.33	29.65	37.19	33.76	30.00	15.59	19.64	19.01	25.14
	P_R-Best-DR	166.70	1.06	16.83	22.36	28.27	33.78	24.82	29.46	24.80	25.83	15.95	14.78	18.93	19.39
	P_R-TNH	166.70	0.84	20.07	29.50	33.97	35.27	34.96	30.91	37.60	38.06	34.04	40.21	40.53	49.84
	P_R-TNH+Best	166.70	0.36	18.73	26.62	32.01	31.88	33.24	27.31	34.09	34.39	25.78	29.35	32.69	42.43
JP	B-Ref_1123	166.70	0.08	20.18	28.87	35.69	38.16	30.48	37.19	33.76	30.00	15.59	31.64	36.76	43.33
	P_R-Best-DR	166.70	1.06	16.83	25.19	30.35	33.78	24.82	29.46	24.80	25.83	15.95	29.05	33.74	39.23
	P_R-TNH	166.70	0.84	20.07	31.96	36.44	36.11	35.80	31.55	40.05	38.06	34.04	40.21	40.96	50.37
	P_R-TNH+Best	166.70	0.36	18.73	29.77	33.75	31.88	33.24	27.31	34.09	34.39	25.78	29.35	32.69	42.43
IS	B-Ref_1123	166.70	0.09	20.18	26.41	33.22	37.33	29.65	37.19	33.76	30.00	15.59	19.64	19.01	25.14
	P_R-Best-DR	166.70	1.06	16.83	22.36	28.27	33.78	24.82	29.46	24.80	25.83	15.95	14.78	18.93	28.47
	P_R-TNH	166.70	0.84	20.07	29.50	33.97	35.27	34.96	30.91	37.60	38.06	34.04	40.21	40.53	49.84
	P_R-TNH+Best	166.70	0.36	18.73	26.62	32.01	31.88	33.24	27.31	34.09	34.39	25.78	29.35	32.69	42.43
SD	B-Ref_1123	166.70	0.09	20.18	26.41	33.22	37.33	29.65	37.19	33.76	30.00	15.59	19.64	19.02	27.10
	P_R-Best-DR	166.70	1.06	16.83	22.36	28.27	33.78	24.82	29.46	24.80	25.83	15.95	14.78	18.93	19.39
	P_R-TNH	166.70	0.84	20.07	29.50	33.97	35.27	34.96	30.91	37.60	38.06	34.53	40.21	40.96	50.37
	P_R-TNH+Best	166.70	0.36	18.73	26.62	32.01	31.88	33.24	27.31	34.09	34.39	25.78	29.35	32.69	42.43
SN	B-Ref_1123	166.70	0.09	20.18	26.41	33.22	38.16	30.48	37.19	33.76	30.00	15.59	19.64	19.01	25.14
	P_R-Best-DR	166.70	1.06	16.83	22.36	28.27	33.78	24.82	29.46	24.80	25.83	15.95	14.78	18.93	19.39
	P_R-TNH	166.70	0.84	20.07	29.50	33.97	36.11	35.80	31.10	37.60	38.06	34.53	40.21	40.96	49.84
	P_R-TNH+Best	166.70	0.36	18.73	26.62	32.01	31.88	33.24	27.31	34.09	34.39	25.78	29.35	32.69	42.43
SP	B-Ref_1123	166.70	0.09	20.18	28.87	35.69	38.16	30.48	38.17	36.21	32.70	18.15	31.64	36.76	38.45
	P_R-Best-DR	166.70	1.06	16.83	25.19	30.35	35.73	26.35	30.22	26.69	27.95	15.95	14.78	18.93	21.76
	P_R-TNH	166.70	0.84	20.07	31.96	36.44	36.11	35.80	31.55	40.05	40.75	36.25	42.85	41.84	51.49
	P_R-TNH+Best	166.70	0.36	18.73	29.77	33.75	33.84	34.77	28.07	35.97	36.26	25.78	29.35	32.69	42.43
SS	B-Ref_1123	166.70	0.09	20.18	26.41	33.22	38.16	30.48	38.17	36.21	32.70	18.15	22.38	20.45	27.10
	P_R-Best-DR	166.70	1.06	16.83	22.36	28.27	35.73	26.35	30.22	26.68	27.95	19.54	24.72	27.10	37.20

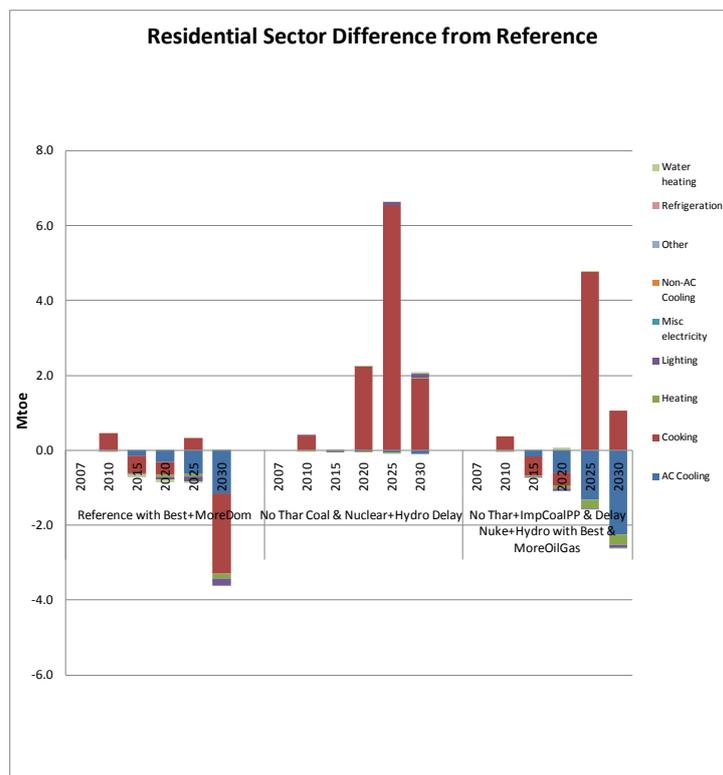
18. Which sectors increase their consumption of natural gas in response to the delay in the large power plant projects, and how much more is needed total in 2030 in the delay scenario without Best?

[residential and industry, along with the power sector – 14Mtoe]



19. What is the increased renewables to the Residential sector used for?

[cooking]



20. What is the impact of the No Thar/delay on the contributors to CO₂ emissions.

[a shift to direct consumption of natural gas particularly by industry results in more emissions from it and the transport sectors than from the power sector in 2030.]

