# TIMES-Starter Model
# Guidelines for Use

***Prepared for the International Energy Agency's***
***Energy Technology Systems Analysis Program (IEA-ETSAP)***


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# 1 Introduction

This report describes the accompanying TIMES[1] Starter model (TIMES-Starter). The underlying premise of the TIMES-Starter model is to provide new users with a well thought out TIMES model structure employing best practices that is built from solid documented data sources. It provides all the basic building blocks, tools and techniques that need to be employed as part of assembling and applying a TIMES model.

The model data is assembled in flexible Excel workbooks (templates) that collectively comprise a viable starting point for development of a TIMES model - both with respect to designing a Reference Energy System (RES) and the depiction of the commodities and technologies underlying that RES. The templates are designed to be driven by the energy balance for any particular area of study (national, regional, municipal), and they are customizable to facilitate more rapid assembly of an initial model by new TIMES users. The intent is to provide a framework and roadmap that enables new users to assemble a high-quality initial model that is tailored as needed to reflect local conditions in a much more expeditious and organized manner.

The TIMES-Starter database is largely derived from the US Environmental Protection Agency Office of Research and Development (EPA-ORD) Nine-Region US MARKAL model (US9r) database[2], which is a peer-reviewed compilation of data from EPA, US Department of Energy (DOE) Annual Energy Outlook (AEO)[3]. Where the EPA database did not provide technologies seen as important (e.g., district heat (HPL) and Coupled Heat & Power (CHP) plants) other credible data sources were turned to, most notably the Danish Energy Agency's[4]. In a few cases, separately referenced, the technology characteristics in the database were updated or expanded, to plug holes or utilize better data. Modeling practices and parameters have been adjusted as needed to move the model data from the MARKAL to the TIMES framework, but the original EPA datasheets are provided to enable (easy) updating when new releases of US9r are made general available. [Full details with respect to the original USDOE AEO source data can be found in the US9r documentation (footnote 2) or by obtaining the full set of templates embodying the model.]

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[1] The Integrated MARKAL/EFOM System, see www.iea-etsap.org.
[2] EPA U.S. Nine-region MARKAL Database, EPA 600/B-13/203, September 2013, http://nepis.epa.gov/Exe/ZyNET.exe/P100I4RX.TXT?ZyActionD=ZyDocument&Client=EPA&Index=2011+Thru+2015&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C11thru15%5CTxt%5C00000009%5CP100I4RX.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=p%7Cf&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL. For access to the US9r templates and database contact Carol Lenox - Lenox.Carol@epa.gov.
[3] Most of the data support the publication by the US Energy Information Administration of the Annual Energy Outlook, http://www.eia.gov/forecasts/aeo/index.cfm).
[4] Link to the main English index for the supply technologies - http://www.ens.dk/en/info/facts-figures/scenarios-analyses-models/technology-data, heating device are only in Dutch at Heat Generation and Datablad for individuelle varmeanlæg og energitransport 2013.

This report serves as a "guidebook" explaining the basic organization, components and functionality of this Starter model, and provides guidelines of how to go about transforming the Starter model into a beginning model for a new application of TIMES. Therefore, the report describes:

- the basics of the approach taken;
- the underlying RES and naming conventions employed;
- each of the TIMES-Starter components;
- additional templates needed to complete the Starter model;
- using the TIMES-Starter model under ANSWER/VEDA/AnalyticsXLS, and
- how to go about adapting the Starter model.

In addition, some examples of common policy questions that the model might be used to explore (e.g., $CO_2$ emission limits or price, renewable and energy efficiency targets) are provided to complete the initial picture of what building and applying a TIMES model entails.

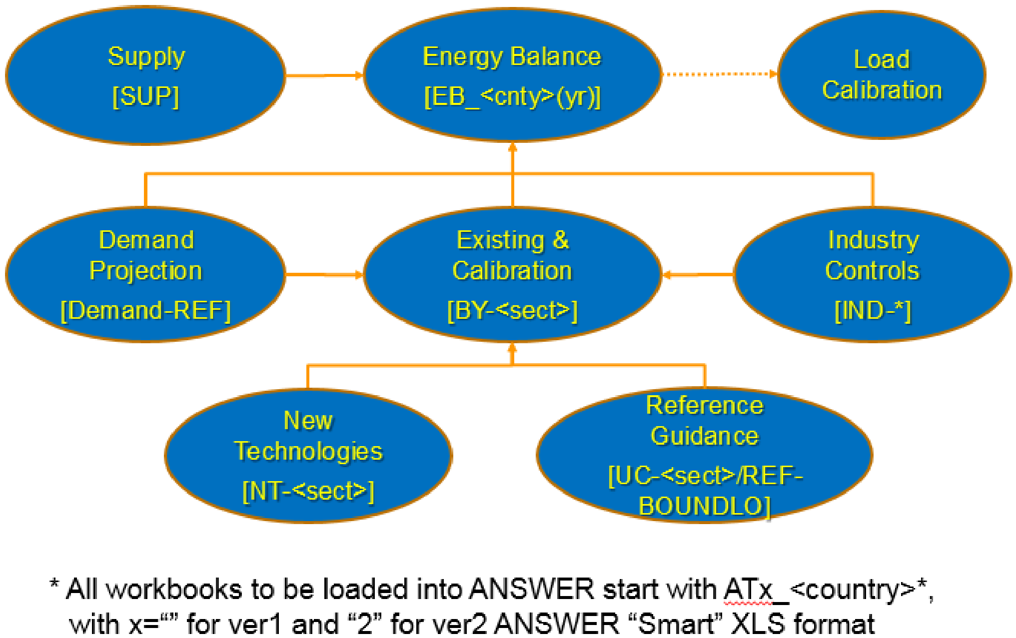
# 2 Organization of the Model Templates

## 2.1 Model Folder Orientation

The complete TIMES-Starter model is assembled in a single sub-folder sitting under the folder AnswerTIMESv6\Databases and named TIMES-Starter(vXX), where XX corresponds to a version number to make it easier to keep track of particular instances of the Starter (or later your own) model, currently v1.0. In this folder are a host of Excel ANSWER “Smart” workbooks that have been organized along the lines depicted in Figure 1, for the Reference or Business-as-Usual (BAU) scenario.

Note that these templates are linked, so that data contained in one workbook can be consistently shared across other dependent templates. The schematic in Figure 1 also shows the inter-dependency between the workbooks, that is where a child links to its parent. When a parent is updated all the dependent children MUST be updated as well (though it may be the case that the actual change does not affect a particular dependent workbook. These relationships are kept in the Dependency Table workbook which can be checked by ANSWER to ensure consistency (of dates), as noted in Section 7.3.

**Figure 1: Schematic of Starter Templates Dependencies**




These workbooks fall into the following categories:

- EB – Energy Balance for the 1st year of the model and current load curve;
- SUP – Resource supply and imports;
- BY – Base year existing technologies and calibration procedure;
- NT – New technology options;
- Demand – Demand drivers and projections;
- IND – Industry configuration, and
- UC - Reference guidance user controls.

Where sector (<sect>) is noted in Figure 1 these correspond to:

- Electric generation technologies [PP];
- Agriculture demand devices [AGR];
- Commercial demand devices and conservation measures [COM];
- Industrial structure and processes, including refineries [IND] *{pending}*;
- Residential demand devices and conservation measures [RSD], and
- Transportation vehicle by mode [TRN].

In addition there are additional workbooks to assist with calibration of the electricity load duration curve (LoadCalibration) and check how the base year results compare to the energy balance (CalibrationCheck_REF) discussed in Section 6. There are also scenario templates (S_<scenario) for setting up alternate scenarios, and the Analytics graph comparison workbook for comparing run results (TIMES-Starter_AXLS) discussed in Section 13.

The naming conventions employed for the templates are explained a bit later in this section.

## 2.2 Template Components

The model data is assembled in ANSWER-TIMES "Smart" Excel workbooks[5] consisting of several worksheets as generally described in Table 1. The list in table does not cover all the sheets in all the workbooks, rather covers mainly the EB, BY and NT core technology templates. The sheets of the more specialized templates, including Supply, Demand, and Reference guidance (UCs and INDs) may have some other special sheets only relevant to them, and will be covered in their respective sections.

The Supply, UC, IND, and some scenario files use Version-1 (v1) of the Smart workbooks, while the majority of the templates use the newer Version 2 (v2), the latter being very similar in layout and functionality to their MARKAL US9r counterparts.

**Table 1: Structure of ANSWER-TIMES Smart Workbooks**

| Worksheet | Description |
|---|---|
| ANSv1-692-Home, ANSv2-692-Home | ANSWER-TIMES template sheet that is used to add new ANSWER-TIMES smart sheet to the current workbook, or turn an existing XLS/XLSM into a "smart" workbook. [Note that the v1 workbooks all begin with AT_ and the v2 workbooks with AT2_.] |
| SETUP | Mapping of EPA-US9r/other names to TIMES TIMES-Starter names and removal of unwanted items, emission factors, and USD price conversion factors. The Setup sheet links to the EB workbook for the list of commodities and emission rates. |
| EB | Information for the Energy Balance workbook for the sector. [BYs only] |
| Regions | Description of Regions for the Database where this instance of the New Techs will be used. [Only active on Supply template.] |
| Calibration | The calculation sheet where the energy balance is apportioned and the initial year technology stock established for each sector. [BYs only] |
| Commodities[6] | Energy carriers, emissions, materials are defined by their name, description, units and set memberships to be used in the rest of the sheets. In V1 templates commodity groups may also be declared. These are in turn controlled by the SETUP sheet, in most cases. [Some v1 templates have an ITEMS sheet that contains both commodity and process declarations.] |
| Processes | Process technologies are defined by their name, description, units and set memberships to be used in the rest of the sheets. These are in turn controlled by the SETUP sheet, in most cases. [Some V1 templates have an ITEMS sheet that contains both commodity and process declarations.] |
| CommData | A sheet with the data for commodities in the sector (mostly used for mapping sector emissions to overall emissions and providing demand levels and load timings. |
| ProcData_<sect> or <nature-of-the-data>[7] | One or more sheets with the data for all technologies in the sector. [Note that the V1 templates have separate TID & TS sheets.] |

[5] See *ANSWERv6-TIMES Smart Excel Workbook Manual* for details on working with / operating the templates.

[6] For v1 templates the Commodities, Process and UC declarations are provided on the ITEMS sheet.

| Worksheet | Description |
|---|---|
| EPA/DEA/PIEM/EC currently (IEA/ETSAP/other_ <sheet>) | Declaration and data sheets from the EPA-US9r/Danish Energy Agency/ Pak-IEM/Energy Community-EE databases (and perhaps other sources including but not limited to IEA, ETSAP eTech-DS, etc.) providing the source values for the technology options. |

All of the Starter workbooks employ the ANSWER-TIMES "Smart" functionality, and have an ANSv1-692or ANSv2-692-Home sheet, and most have an EB and SETUP sheet to enable easy inclusion/exclusion of commodities (based initially on the EB) and technologies (according to the active commodities and defined process components). Explicitly excluding a commodity or technology/process is handled by putting a "*" in Col-A. The Commodity/Process declaration and Comm/ProcData data sheets then carry along the "*" to have them ignored by ANSWER during the import process. If a commodity that does not appear in the current energy balance is needed in the future (for a new technology option), then it needs to be "activated" on the BY EB sheet by deleting the 0 carried from the EB.

The TIMES-Starter has a wide range of commodities and process for almost every situation. However, as every country has some unique features, the addition of a new commodity or process may be required. See Section 14.2.2 for a discussion of the process for adding new commodities or processes.

The ANSWER BASE scenario is manually loaded with the Global parameters related to discounting (year and global rate), and annual timeslices. With regard to the latter, the model is setup for four (4) seasons and three (3) divisions of the day for a total of twelve (12) timeslices. These timeslices are established in the LoadCurve workbook, but also found in the EB workbook where each BY and the Demand Projection workbooks link to them. The values in the TimePeriods & FRs tab of the EB_Starter(2013) template are laid out so that they can be directly copied and pasted into ANSWER if they need to be changed. Section 6 discusses how to adjust the LoadCurve workbook. Note that adjusting the number of timeslices or the inter-relationships between timeslices is certainly doable, but this would need to be done with care as there are lots of interdependencies and recalibration will be necessary along with modifying the LoadCurve calculation workbook. *Therefore, changing the number of timeslice is beyond the scope of the initial Starter model and will instead be discussed at a later time in a planned Intermediate Guide for the TIMES-Starter model.*

## 2.3 Connecting with the EPA US9r Data

The technology characterization data comprising the ANSWER-TIMES (ProcData) load sheets links directly to a copy of the equivalent US9r ANSWER-MARKAL (or other) load sheets, unless otherwise stated. The Excel VLOOKUP function is used to grab the data by mapping the EPA process name to the corresponding Starter process names as assembled on the SETUP sheet. This is accomplished by means of the entry in Col-H of the ProcData sheets, which in turn is grabbed from Col-D on SETUP based upon the Starter process name in Col-B of the same row.

[7] For the v1 templates data is loaded from the TS&TID Data sheet for standard processes and UCs, and from separate TOP/TID/TS_Data sheets for Supply. [Nature-of-the-data refers to power plant or vehicle type when there are numerous types for a sector.]

There is a rather extensive set of technologies in the full US9r database (workbook), including multiple wind classes with different price points, old and future power plants of various types, retrofit and new FGD options, and much more. The user is encouraged to obtain the full US9r documentation (see Footnote #2).

On each ProcData sheet above the TIMES Parameter (in row 4), the corresponding MARKAL parameter name is provided for reference. This also then establishes the column on the source data sheet where the information is to come from. The VLOOKUP function then references that column in the EPA data sheet and the look-up range is set to cover the entire data set, which ensures capturing the correct value. Also, note that the model periods come from the Setup sheet, which is linked to the EB sheet and thus the user should carefully ensure that the correct column is grabbed from the US9r data there. This is done as part of the VLOOKUP by means of the displacement count parameter, which is thus sensitive to any changes in the column order on the EPA source data sheet.

In addition, there are some transformations performed on the source data when and where needed. The most notable is for all costs, where the SETUP monetary conversion factor is set to bring all costs to 2013 US dollars. Others include converting from miles to kilometers for transport, and in the case of power plants inverting the input value (MARKAL) to efficiency (TIMES). We can see this in Figure 2 showing the MARKAL/TIMES templates (top/bottom) where Start=NCAP_START, LIFE=NCAP_LIFE, etc. as reflected in rows 3-4 of the latter, then for the most part the columns run across the worksheet in the same order, with some columns skipped over (hidden below).

## Figure 2: Aligning TIMES-Starter & MARKAL US9r Parameters/Data

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | xTechData | _GLOBAL,R0,R1,R2,R3,R4,R5,R6,R7,R8,R9 | | | | | | | | | | | | | | | |
| 2 | Index | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 3 | | | | | | | | | | | | | | | | | |
| 4 | Check Sht | TechName, TechDesc, TACT, TCAP Units | | Refresh Units | Comm IN | Comm OUT | | | | | | | | | | | |
| 5 | Parameter | | | | | | START | LIFE | CAPUNIT | OUT(ELC)_TID | PEAK(CON) | AF | FIXOM | VAROM | INP(ENT)c | INP(ENT)c | INP(ENT)c |
| 6 | Qualifier | | | | | | | | | | | | | | | | |
| 7 | | TechName | TechDesc | Units | CommIN | CommOUT | TID | TID | TID | TID | | | | | 2005-2015 | 2020 | 2025-2055 |
| 8 | R1,R2,R3,R4,R5, | ECSTMRBONR | Residual Coal Steam; Bituminous; Over 100 MW; 2010;Recirculated | PJ, GW | CSTMBIT50 | ELC | 2010 | 45 | 31.536 | 1 | 0.95 | 0.9 | 27.3 | 1.09 | 2.58 | 2.57 | 2.56 |
| 9 | R1,R2,R3,R4,R5, | ECSTMRSONR | Residual Coal Steam; Subbituminous; Over 100 MW; 2010; Recirculated | PJ, GW | CSTMSUB50 | ELC | 2010 | 45 | 31.536 | 1 | 0.95 | 0.9 | 27.3 | 1.09 | 2.58 | 2.57 | 2.56 |
| 10 | R1,R2,R3,R4,R5, | ECSTMRLONR | Residual Coal Steam; Lignite; Over 100 MW; 2010; Recirculating | PJ, GW | CSTMLIG50 | ELC | 2010 | 45 | 31.536 | 1 | 0.95 | 0.9 | 27.3 | 1.09 | 2.58 | 2.57 | 2.56 |
| 11 | R1,R2,R3,R4,R5, | ECOALSTM | Pulverized Coal Steam - from 2015 | PJ, GW | COALSTMCC | ELC | 2015 | 50 | 31.536 | 1 | 0.95 | 0.9 | 27.3 | 1.09 | 2.58 | 2.57 | 2.56 |
| 12 | R1,R2,R3,R4,R5, | ENGACC10 | Natural Gas - Combined-Cycle (Turbine) | PJ, GW | ELCNGACC | ELC | 2005 | 30 | 31.536 | 1 | 0.95 | 0.9 | 11.54 | 0.88 | 2.22 | 2.22 | 2.22 |
| 13 | R1,R2,R3,R4,R5, | ENGACC15 | Natural Gas - Combined-Cycle (Turbine) | PJ, GW | ELCNGACC | ELC | 2015 | 30 | 31.536 | 1 | 0.95 | 0.9 | 11.54 | 0.88 | 2.07 | 2.07 | 2.07 |
| 14 | R1,R2,R3,R4,R5, | ENGACC | Natural Gas - Combined-Cycle (Turbine) | PJ, GW | ELCNGACC | ELC | 2020 | 30 | 31.536 | 1 | 0.95 | 0.9 | 11.54 | 0.88 | 2.07 | 2.03 | 1.99 |
| 15 | R1,R2,R3,R4,R5, | ENGAACC | Natural Gas - Advanced Combined-Cycle (Turbine) | PJ, GW | ELCNGACC | ELC | 2020 | 30 | 31.536 | 1 | 0.95 | 0.9 | 13.5 | 0.80 | 1.88 | 1.87 | 1.86 |
| 16 | R1,R2,R3,R4,R5, | ENGACT10 | Natural Gas - Combustion Turbine | PJ, GW | ELCNGAEA | ELC | 2005 | 30 | 31.536 | 1 | 0.95 | 0.9 | 6.43 | 3.76 | 3.33 | 3.33 | 3.33 |
| 17 | R1,R2,R3,R4,R5, | ENGACT15 | Natural Gas - Combustion Turbine | PJ, GW | ELCNGAEA | ELC | 2015 | 30 | 31.536 | 1 | 0.95 | 0.9 | 6.43 | 3.76 | 3.20 | 3.20 | 3.20 |
| 18 | R1,R2,R3,R4,R5, | ENGACT | Natural Gas - Combustion Turbine | PJ, GW | ELCNGAEA | ELC | 2020 | 30 | 31.536 | 1 | 0.95 | 0.9 | 6.43 | 3.76 | 3.20 | 2.90 | 2.60 |
| 19 | R1,R2,R3,R4,R5, | ENGAACT | Natural Gas - Advanced Combustion Turbine | PJ, GW | ELCNGAEA | ELC | 2020 | 30 | 31.536 | 1 | 0.95 | 0.9 | 6.2 | 2.52 | 2.86 | 2.68 | 2.51 |
| 20 | R1,R2,R3,R4,R5, | ECOALIGCC | Integrated Coal Gasif. Combined Cycle | PJ, GW | COALIGCCCC | ELC | 2015 | 40 | 31.536 | 1 | 0.95 | 0.9 | 45.0 | 1.76 | 2.55 | 2.37 | 2.18 |
| 21 | R1,R2,R3,R4,R5, | EBIOIGCC | Biomass Integrated Gasification Combined-Cycle | PJ, GW | ELCBIGCCEA | ELC | 2010 | 35 | 31.536 | 1 | 0.9 | 0.9 | 92.5 | 1.28 | 3.96 | 3.96 | 3.96 |
| 22 | R8,R9 | EGEOBCFS | Geothermal - Binary Cycle and Flashed Steam | PJ, GW | ELCGEO | ELC | 2010 | 30 | 31.536 | 1 | 0.9 | 0.9 | 98.9 | 0.00 | 2.85 | 2.85 | 2.85 |
| 23 | R8,R9 | EGEOEGS | Geothermal - Enhanced Geothermal System | PJ, GW | ELCGEO | ELC | 2025 | 30 | 31.536 | 1 | 0.9 | 0.9 | 275.37 | 14.54 | 2.85 | 2.85 | 2.85 |
| 24 | R1,R2,R3,R4,R5, | EURNALWR15 | Nuclear LWRs in 2015 | PJ, GW | URNA | ELC | 2015 | 45 | 31.536 | 1 | 0.95 | 0.9 | 81.7 | 0.52 | | | |
| 25 | | | | | | USPTA | | | | | | | | | | | |

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ProcData | STARTER | | | | | | * | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | | | | | |
| 3 | Check Sheet | ProcName, ProcDesc, Units | | | CommIN | CommOUT | | | START | LIFE | CAPUNIT | PEAK(CON) | | | AF | FIXOM | VAROM | INP(ENT)c | RESID | IBOND(UP) | IBOND(UP) |
| 4 | Parameter | | If Process Activity is: Output-based, leave blank. Input-based, insert I. | | * | | | | NCAP_STAR | NCAP_TLIFE | PRC_CAPAC | NCAP_PKCN | NCAP_AFA- | NCAP_AFA- | NCAP_AF-UI | NCAP_FOM | ACT_COST | ACT_EFF | NCAP_PAST | NCAP_BND-I | NCAP_BND-UP |
| 5 | Qualifier1 | | | | | | | | | | | ANNUAL | | | ANNUAL | | | ACTGRP | 2013 | | |
| 6 | Qualifier2 | | | | | | | | | | | | | | | | | ANNUAL | | | |
| 7 | | ProcName | ProcDesc | ProcUnits | CommIN | CommOUT | Activity I/O | Tech Lookup | TID | | TID | | 2013 | 0 | 2015 | | | | TID | 0 | |
| 8 | * Standard Power Plants | | | | | | | | | | | | | | | | | | | | |
| 9 | | EECOAOBC-ST-X0 | Bituminous (Brown Coal) - Steam turbine (Existing) | PJ,GW | PWRCOAOE | ELCT | | ECSTMRBONR | 2013 | 12 | 31.536 | 0.95 | 0.79 | 1 | 0.90 | 31.70 | 1.26 | 0.33 | 0.06 | 5 | 0 |
| 10 | | | | | | | | | | | | | | | | | | | | | |
| 11 | | EECOASBC-ST-X0 | Sub-Bituminous Coal - Steam turbine (Existing) | PJ,GW | PWRCOASB | ELCT | | ECSTMRSONR | 2013 | 12 | 31.536 | 0.95 | 0.79 | 1 | 0.90 | 31.70 | 1.26 | 0.33 | 0.06 | 5 | 0 |
| 12 | | | | | | | | | | | | | | | | | | | | | |
| 13 | | EEGASNAT-CC-X0 | Natural Gas - Combined cycle (Existing) | PJ,GW | PWRGASNA | ELCT | | ENGACC10 | 2013 | 17 | 31.536 | 0.95 | 0.86 | 1 | 0.90 | 13.39 | 1.02 | 0.45 | 0.11 | 5 | 0 |
| 14 | | | | | | | | | | | | | | | | | | | | | |
| 15 | | EEGASNAT-CT-X0 | Natural Gas - Combustion turbine (Existing) | PJ,GW | PWRGASNA | ELCT | | ENGACT10 | 2013 | 12 | 31.536 | 0.95 | 0.71 | 1 | 0.90 | 7.46 | 4.36 | 0.28 | 0.15 | 5 | 0 |
| 16 | | | | | | | | | | | | | | | | | | | | | |
| 17 | | EECOALIG-IG-X0 | Lignite - Integrated Gasif. (Existing) Combined cycle | PJ,GW | PWRCOALIC | ELCT | | ECOALIGCC | 2013 | 27 | 31.536 | 0.95 | 0.63 | 1 | 0.90 | 52.24 | 2.04 | 0.34 | 0.05 | 5 | 0 |
| 18 | | | | | | | | | | | | | | | | | | | | | |
| 19 | | EENUCLER-LWR-X0 | Nuclear - LWR (Existing) | PJ,GW | PWRNUCLEI | ELCT | | EURNALWR15 | 2013 | 22 | 31.536 | 0.95 | 0.87 | 1 | 0.90 | 94.82 | 0.60 | 0.34 | 0.4 | 5 | 0 |
| 20 | | | | | | | | | | | | | | | | | | | | | |
| 21 | | EECOALIG-ST-X0 | Lignite - Steam turbine (Existing) | PJ,GW | PWRCOALIC | ELCT | | ECSTMRLONR | 2013 | 17 | 31.536 | 0.95 | 0.48 | 1 | 0.90 | 31.70 | 1.26 | 0.33 | 0.1 | 5 | 0 |
| 22 | | | | | | | | | | | | | | | | | | | | | |

Note that US9r source data sheets mix existing and new technologies. However, for TIMES-Starter the existing technologies and new technologies are maintained in separate templates, so the original US9r source data sheet will appear in both workbooks, for each sector. But with respect to the existing processes modelers need to compare the characteristics of their existing set of technologies against those of the new standard new technologies to ensure that any impacts of local conditions are factored into the data. For example, the plant conversion efficiency might be adjusted lower due to higher ambient temperatures, or the investment cost increased because a dry-cooling water system is required.

The TIMES-Starter workbooks also detect changes in efficiency over time, and as necessary set the TIMES Vintage flag, so that said efficiencies are tied to the processes according to the year of investment rather than current model period.

In October 2016, the USEPA-ORD will release the first update to the US9r model following the creation of the TIMES-Starter model. In discussion with USEPA-ORD they have agreed to provide a clear summary of every STRUCTURAL change to their templates, particularly with respect to the column order. Knowing this, what is envisioned for updating the TIMES-Starter is that the updated US9r MARKAL data load sheets will be able to be copied (using Copy/PasteValues) over the existing corresponding TIMES-Starter worksheet, updating all the numbers. The VLOOKUP functions will need to be modified for any column changes, and the VLOOKUP range expanded as needed to capture any new processes added to US9r data set. These new processes and any new commodities they require will need to be added to the SETUP/Commodity/Process/ProcData tabs as necessary. A discussion on adding new processes can be found in Section 14.

## 2.4 Template Naming Conventions

The templates employ a simple naming convention consisting of AT(2)_<country>_<nature>-<sector>, where all load templates start with AT (for ANSWER-TIMES) and

- (2) indicates those templates employing the newer version 2 (v2) smart templates, as opposed to AT_ for the original version 1 (v1) templates;
- <country> is currently STARTER, but should be replaced by the country or region name;
- <nature> indicates the type of template, e.g., BY=base year, NT=New Tech, etc., and
- <sector> indicates the specific energy or demand sector

Supply, IND, UC and some scenario files use the v1 format, but the majority of the templates are in the v2 format. The ANSWER-TIMESver2-692.xlsm file is an empty template that may be used to create new v2 templates (ANSWER-TIMESver1-692 for v1), but more likely changes will involve modifying an existing TIMES-Starter templates or copying them to make new ones. The list of current templates is shown in Table 2.

Note that some workbooks are linked to others and should be handled as a pair (that is opening both together) when making changes or renaming the parent (linked to) template. However, it is recommended that one does not change workbook template names, rather make new folders and make your changes there so that the inter-dependencies are consistent, and the ANSWER Import Scenario remembering the template(s) for each scenario remains intact. [Every once and a while when opening a workbook it’s a good idea to check “Data/Edit Links” to make sure the folder/files are pointing to the correct instance of the parent/grandparent.]

To help ensure that the workbooks are properly synchronized (that is all children have a last saved date newer than that of all their ancestors) ANSWER supports a Workbook Dependency Check facility at Import time. These dependencies are reflected in Figure 1 and Table 2. It is recommended that after importing changed (dependent) templates into ANSWER the user resave the DependencyXLS – so that when sorted by date it serves as a reminder of those changed since last import. Also, if the user therefore does choose to change of the name of a template they are strongly encouraged to also remember to change the Dependency table. There is a bi-directional dependency between the LoadCalibration and EB_Starter workbooks, though neither is actually loaded into ANSWER. As such only a change in the LoadCalibration is monitored. When updating many templates the easiest way to proceed in terms of meeting the dependency criterial is to make the changes in the order listed in the Child Templates column of the table below.

**Table 2: ANSWER Templates Dependency Table**

| TIMES-Starter Template Dependencies | |
|---|---|
| **Linked Child Templates** | **Parent/GrandParent Template** |
| | |
| EB_Starter(2013).xlsm | Starter_LoadCalibration.xls |
| AT_Starter_SUP.xlsm | EB_Starter(2013).xlsm |
| AT2_Starter_BY-AGR.xlsm | EB_Starter(2013).xlsm |
| AT2_Starter_BY-COM.xlsm | EB_Starter(2013).xlsm |
| AT2_Starter_BY-IND.xlsm | EB_Starter(2013).xlsm |
| AT2_Starter_BY-PP.xlsm | EB_Starter(2013).xlsm |
| AT2_Starter_BY-RSD.xlsm | EB_Starter(2013).xlsm |
| AT2_Starter_BY-TRN.xlsm | EB_Starter(2013).xlsm |
| AT2_Starter_Demand-REF.xlsm | EB_Starter(2013).xlsm |
| | AT2_Starter_BY-AGR.xlsm |
| | AT2_Starter_BY-COM.xlsm |
| | AT2_Starter_BY-IND.xlsm |
| | AT2_Starter_BY-RSD.xlsm |
| | AT2_Starter_BY-TRN.xlsm |
| AT2_Starter_NT-AGR.xlsm | AT2_Starter_BY-AGR.xlsm |
| AT2_Starter_NT-COM.xlsm | AT2_Starter_BY-COM.xlsm |
| AT2_Starter_NT-PP.xlsm | AT2_Starter_BY-PP.xlsm |
| AT2_Starter_NT-RSD.xlsm | AT2_Starter_BY-RSD.xlsm |
| AT2_Starter_NT-TRN.xlsm | AT2_Starter_BY-TRN.xlsm |
| AT_Starter_UC-COM.xlsm | AT2_Starter_BY-COM.xlsm |
| AT_Starter_UC-COM-50.xlsm | AT2_Starter_BY-COM.xlsm |
| AT_Starter_UC-COM-90.xlsm | AT2_Starter_BY-COM.xlsm |
| AT_Starter_UC-RSD.xlsm | AT2_Starter_BY-RSD.xlsm |
| AT_Starter_UC-RSD-50.xlsm | AT2_Starter_BY-RSD.xlsm |
| AT_Starter_UC-RSD-90.xlsm | AT2_Starter_BY-RSD.xlsm |
| AT_Starter_UC-TRN.xlsm | AT2_Starter_BY-TRN.xlsm |
| AT_Starter_UC-TRN-50.xlsm | AT2_Starter_BY-TRN.xlsm |
| AT_Starter_UC-TRN-90.xlsm | AT2_Starter_BY-TRN.xlsm |
| REF_BOUNDLO.xlsm | AT2_Starter_BY-PP.xlsm |
| REF_BOUNDLO-RED.xlsm | AT2_Starter_BY-PP.xlsm |
| AT_Starter_ZZDMY.xlsm | AT_Starter_SUP.xlsm |
| | AT2_Starter_Demand-REF.xlsm |

* Global data needs to be manually copied into BASE if changed from EB template

The templates are managed and loaded into the ANSWER-TIMES database as discussed in Section 7.

Note that if one encounters a problem with an ANSWER "Smart" XLS not functioning properly, saving the current templates as an XLSX (that is, workbook without macros) and then using the ANSWER-TIMES template "Master" to update this XLSX to an XLSM is a strategy that should overcome problematic XLSM functionality.

# 3 RES Component Naming Conventions and Units

Good practice for TIMES models is to employ strict naming conventions for both energy carrier and technology names encompassing the Reference Energy System (RES). Table 3 provides the three components of each energy carrier name. Each energy carriers has a core three-character identifiers (e.g., OIL, COA, RNW). In the database, these core names are preceded by a three-character sector identifier that indicates which sector the energy carrier is being supplied from (SUP) or to (all others), and may include a qualifier identifying a subset of the core energy carrier group (e.g., hard coal, diesel oil, etc.) it is associated with. For example, supply of hard/brown coal to all sectors is SUPCOAHRD/BRO, while coal for electric generation is PWRCOAHRD/BRO, and COMELC is electricity supplied to the commercial sector. Where it is not necessary to qualify the "root" it can be omitted (e.g., electricity). Rigorously employing such naming conventions, and being strict to include unique key words the description (e.g., "existing" for all technologies in place today) is critical to ensuring the correct functioning of the current process and commodity sets in the Starter model that enable the power of VEDA_Back-End (VBE) and the ANSWER Named Filters to be fully exploited.

**Table 3: Commodity Naming Conventions**

| Energy Carrier Root | Description | | Energy Carrier Qualifier[8] | Description |
|---|---|---|---|---|
| BIO | Biomass | | ANT | Anthracite |
| COA | Coal | | PSF | Biomass (primary solid fuel) |
| GAS | Natural Gas | | BIT | Bituminous |
| NUC | Nuclear | | BRI | Briquettes |
| OIL | Oil and Oil Products | | CCO | Coke |
| RNW | Renewables | | COI | Crude |
| Other | Will be added as needed | | DSL | Diesel |
| | | | FOI | Fuel Oil |
| **Energy Sector** | **Description** | | GEO | Geothermal |
| AGR | To Agriculture sector | | GSL | Gasoline |
| COM | To Commercial sector | | HYD | Hydro |
| IND | To Industrial sector | | JET | Jet Fuel |
| PWR | To Electric Generation | | KER | Kerosene |
| RSD | To Residential sector | | LFG | Landfill Gas |
| SUP | Supply & Imports/Exports | | LIG | Lignite |
| TRN | To Transportation sector | | LNG | Liquefied Natural Gas |
| | | | LPG | Liquefied Petroleum Gas |
| | | | MSW | Municipal Solid Waste |
| | | | NAT | Natural Gas |
| | | | PET | Peat |
| | | | RFO | Residual Fuel Oil |
| | | | SOL | Solar |
| | | | WAS | Waste |
| | | | WIN | Wind |
| | | | URN | Uranium |
| | | | Others | Will be added as needed |
| | | | | |

[8] Note that some Energy Carriers in the IEA energy balance are not listed in this table.

Similarly, naming conventions for technologies look to identify aspects of the sector or demand service (perhaps by type (e.g., rural/urban households, public/private buildings)), and nature of the technology (e.g., power plant or device type, fuel consumed, kind of demand device, and quality of the device). For example, the residential heating devices in Figure 3 have their names built as:

- Sector: R - Residential
- Service: H - Heating
- Building Type: B - Households [could have >1 type]
- Fuel: GASNAT – Natural Gas
- Device Type F/HA/R - Furnace/Air Heat Pump/Radiant
- Device Quality ST/IM/BE/AD - Standard/Improved/Best/Advanced for conventional to most efficient

**Figure 3: Demand Device Naming Example - Residential Household Heating Devices**

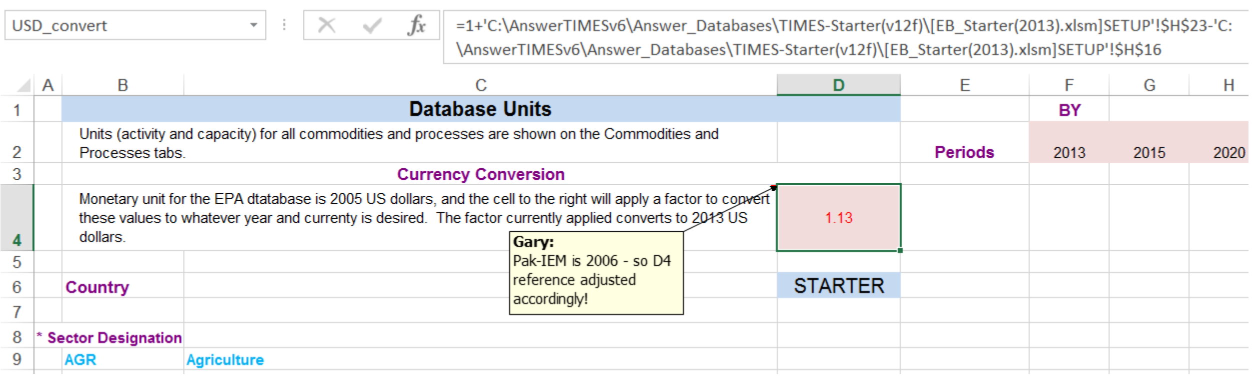
| TIMES | Description | EPA |
|---|---|---|
| * Building Type | | |
| * Space Heating | | |
| * Electric Radiant | | |
| RHBELC-R-ST | Residential Heating: Electricity Radiant-Standard | RSHERDV110 |
| * Electric Heat Pump | | |
| RHBELC-HA-ST | Residential Heating: Electricity Heat Pump-Standard | RSHEHPV110 |
| RHBELC-HA-IM | Residential Heating: Electricity Heat Pump-Improved | RSHEHPV210 |
| RHBELC-HA-BE | Residential Heating: Electricity Heat Pump-Best | RSHEHPV310 |
| RHBELC-HA-AD | Residential Heating: Electricity Heat Pump-Advanced | RSHEHPV410 |
| * Natural Gas Furnace | | |
| RHBGASNAT-F-ST | Residential Heating: Natural Gas Furnace-Standard | RSHNFRV210 |
| RHBGASNAT-F-IM | Residential Heating: Natural Gas Furnace-Improved | RSHNFRV310 |
| RHBGASNAT-F-BE | Residential Heating: Natural Gas Furnace-Best | RSHNFRV410 |
| RHBGASNAT-F-AD | Residential Heating: Natural Gas Furnace-Advanced | RSHNFRV510 |
| * Natural Gas Radiant | | |
| RHBGASNAT-R-ST | Residential Heating: Natural Gas Radiant-Standard | RSHNRDV110 |
| RHBGASNAT-R-IM | Residential Heating: Natural Gas Radiant-Improved | RSHNRDV210 |
| RHBGASNAT-R-BE | Residential Heating: Natural Gas Radiant-Best | RSHNRDV310 |
| * Kerosene Furnace | | |
| RHBOILKER-F-ST | Residential Heating: Kerosene Furnace-Standard | RSHKFRV110 |
| RHBOILKER-F-IM | Residential Heating: Kerosene Furnace-Improved | RSHKFRV210 |

In the sector sections that follow the approach, components and some examples of each technology group are given.

In terms of units, in the US9r database all costs are expressed in 2005 US dollars, and the workbooks have all been designed with a conversion factor on the SETUP sheet (cell D4 as USD_Convert) to allow conversion to other years and currencies. The current conversion factor is set to calculate cost parameters in 2013 US dollars, which corresponds to the first year of the model. However, the

Agriculture data, not available from US9r, is in 2006 US$ so the USD_Convert needs be adjusted by referring to the EB USD conversion table, as should below. Note that in the case of the DEA data a different approach was taken were work was done on the source data sheet to convert from Euros to Dollars, where it so happens the costs are in 2005Euros so not inflating/deflating is necessary.

**Figure 4: Setting USD_Convert for a Particular Sector (Agriculture)**




In terms of the commodity and technology attribute units:

- Energy - Petajoules (PJ);
- Capacity - Gigawatts (GW) for power sector, Petajoules/annum (PJa) for most others, and kilometer index for transportation;
- Demand - most are Petajoules, with some transportation in passenger/freight kilometers and lighting in lumens, and
- Emissions - Million/Thousand Tons (Mt/Kt).

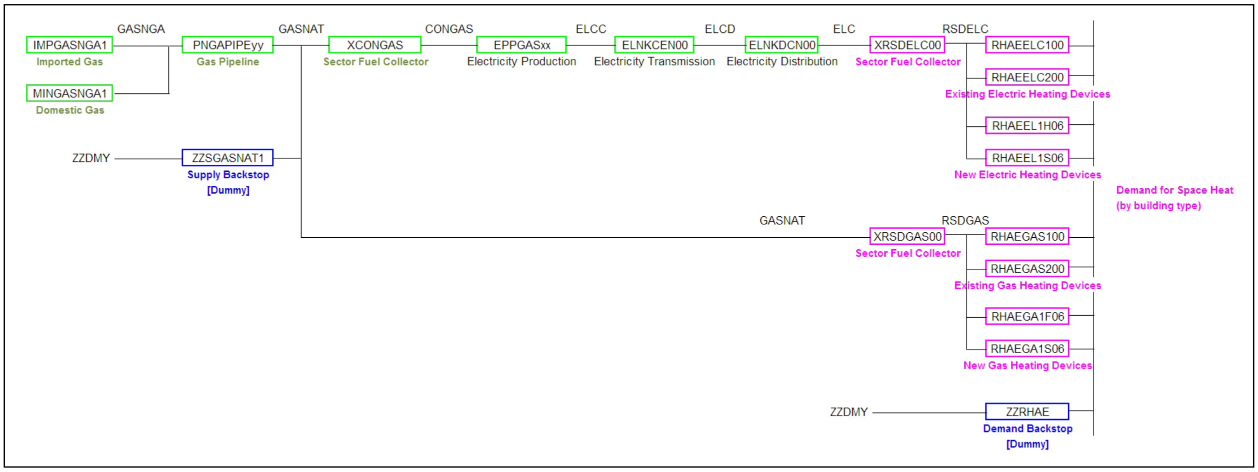
Note that some of the transportation demands are in terms of Billion Vehicle Miles (bvm) in US9r which are then converted to Billion Vehicle Kilometers (bvk) for the TIMES-Starter.

# 4 Organization of the TIMES-Starter RES

All TIMES models are organized around the principles of the Reference Energy System (RES) network. The RES connects processes (e.g., resource supply, power plants, refineries, pipelines, demand devices) that produce/consume commodities (energy, materials, emissions) by means of identifying the flow of the commodities from / into the processes. This network then manages the underlying energy system to ensure the flows balance and that each of the process is properly characterized in terms of where it "fits" in the energy system. The key to this simple approach is the requirement that the name of each commodity changes when exiting a process, where, as discussed in the next sections, employing strict naming conventions make it easy to identify each process and commodity within the RES.

Figure 5, while not from the Starter model, shows the basic approach to organizing the RES. Resources are imported/mined, in this case natural gas, then moved via a pipeline to either the power or demand sectors (here Residential), where a "dummy" sector exchange process (beginning with "X") converts the name of the upstream gas supply to that of the corresponding sector (retaining the word "GAS" in its name to facilitate set definition and filtering later). When the gas is consumed to generate electricity that commodity stream kicks in and centralized electricity is sent along the transmission lines to the distribution network, where consumption is then tracked by demand sector (retaining "ELC" in the commodity name throughout).

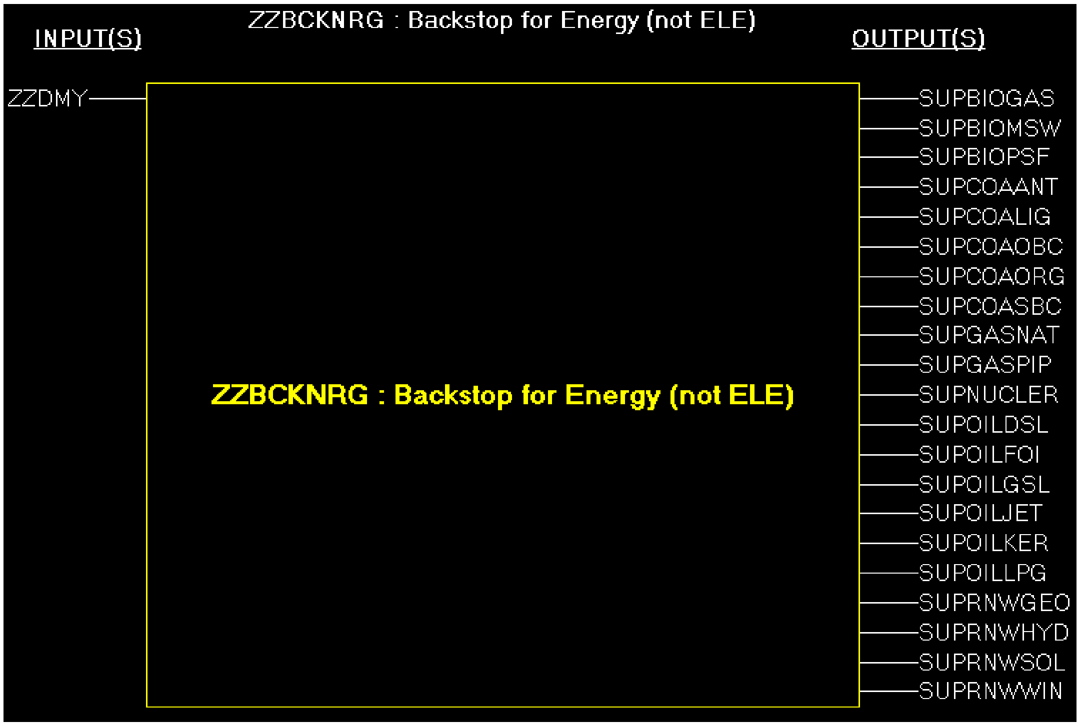
**Figure 5: Basic RES Organization Principles**




Thus, as part of employing good RES design principles, processes are often inserted at convenient points in the network for the purposes of facilitating tracking, collecting, and distinguishing aspects of the underlying energy system. One such convention employed is the use of X<sector><fuel> processes (see XCONGAS in Figure 5) to channel commodities between upstream sources and the various sectors modeled, where the processes' main purpose is to change the name of the commodity to its sector counterpart. These may also serve as an appropriate place to track sector emissions (by fuel), apply sector delivery charges, reflect losses in the distribution system, and reflect limits/cost of expanding infrastructure.

Another good TIMES modeling practice that greatly aids in model debugging is to employ "backstop" processes that can produce the main commodities in the energy system by consuming a dummy commodity at an extremely high cost. These backstop processes (typically named ZZBCK<type> ) are setup to produce all conventional energy carriers, electricity, and demand services that are currently used in the model to help avoid infeasibilities that may arise due to a production shortfall or RES connectivity problem --- the most common cause of infeasibilities (along with inconsistent bounds). A typical ZZBCKNRG process for energy is shown in Figure 6, where a ZZBCKELC (operating at the timeslice level) and ZZBCKDEM are also created to supply unmet electricity or service demand(s). If a ZZBCK process is called upon, it can be readily identified in the solution because the impact of its high cost will increase the objective function value dramatically.

**Figure 6: Backstop Process to Avoid (Most) Infeasible Solutions**




# 5 A Look at the Input Data Workbooks

This section describes by sector the nature of the various input data sheets found in the main templates that comprise the model. The type of sheets found in the workbooks were discussed in Section 2.2, while here the content with respect to the model data is the focus.

Here all the examples shown, with the exception of Supply, present the New Technology (NT) templates to get across the nature of the information needed, and where and how it is organized in the template. How to go about augmenting the information found in the templates, most notably adding/removing commodities and processes, and/or making entire new sub-sectors (e.g., splitting households into urban and rural) or new regions, is discussed in Section 14.

Before going through the templates a critical aspect of how TIMES handles input data with respect to interpolation / extrapolation is warranted in terms of what is most commonly used in the Starter model. The interpoltion rules are explained in the ETSAP TIMES documentation (http://www.iea-etsap.org/web/Documentation.asp). In the input templates whenever the Period=0 for any paramter the value provided corresponds to the override of the default interpolation rule. In the Starter (and most TIMES models) the I/E override is employed for:

- Restricting investment in existing processes and devices via i/e=12 for NCAP_BND (setting it to eps for all periods);

- Keeping shares in place over the modeling horizon with i/e=5 for FLO_SHARE/MARK (interpolate and extend constant), and
- Extending the RHS=0 for UCs via i/e=5 (interpolate and extend constant).

There may of course be other instances where the I/E default is overridden, but these are used the most common ones. The rest of the parameters are usually interpolated with extrapolation constant, as their default. The table from the TIMES documentation is shown below.

*Table 2. Option Codes for the control of data interpolation*

| 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 at end-points, no extrapolation | 11 | Bounds, RHS |
| Interpolation migrated at ends, extrapolation with EPS | 12 | Bounds, RHS |
| Interpolation migrated at end, backward extrapolation | 14 | Bounds, RHS |
| Interpolation migrated at start, forward extrapolation | 15 | Bounds, RHS |
| Log-linear interpolation beyond YEAR | YEAR (≥1000) | All |

## 5.1 Energy Balance

The process of depicting the energy system for a TIMES model starts from the complete first year energy balance. For the TIMES-Starter a typical energy balance for 2013 is used. Thus the first step in adapting the TIMES-Starter for another energy system is to properly enter the associated energy balance. The layout of the TIMES-Starter Energy Balance worksheet corresponds to that published by the IEA. Because many of the other templates are driven by the Energy Balance, its layout, as seen in Figure 7, should be considered rigid and should not be changed. [If a fuel is missing for your energy system you can (carefully) take over one of the other fuels (columns) that you don't need, as long as you follow the naming conventions discussed earlier.]

## Figure 7: Energy Balance Sheet

| Country (Region) Name | OILLPG | OILGSL | OILJET | OILKER | OILDSL | OILFOI | OILNAP | OILLUB | OILBIT | OILPCO | OILNSO | GASNAT | BIOIWA | BIOMSW | BIOPSF | BIOGAS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PJ | LPG | Gasoline | Jet Fuel | Kerosene | Diesel | Fuel Oil | Naphtha | Lubricants | Bitumen | Petroleum Coke | Non-specified Oil Products | Natural Gas | Industrial Waste | Municipal Waste | Primary Solid Biofuels | Biogases |
| Main activity producer electricity plants | - | - | - | - | | | - | - | - | - | - | 15.00 | - | 3.00 | 15.00 | 3.00 |
| Autoproducer electricity plants | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Main activity producer CHP plants | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Autoproducer CHP plants | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Main activity producer heat plants | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Autoproducer heat plants | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Heat pumps | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Electric boilers | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Chemical heat for electricity production | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Gas works | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Oil refineries | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Coal transformation | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Liquefaction plants | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Non-specified (transformation) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Energy industry own use | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Losses | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Final consumption** | **0.75** | **16.47** | **0.03** | **0.01** | **17.48** | **0.18** | **-** | **-** | **-** | **-** | **-** | **32.61** | **-** | **-** | **20.14** | **-** |
| **Industry** | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Iron and steel | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Chemical and petrochemical | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Non-ferrous metals | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Non-metallic minerals | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Transport equipment | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Machinery | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Mining and quarrying | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Food and tobacco | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Paper, pulp and print | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Wood and wood products | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Construction | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Textile and leather | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Non-specified (industry) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Transport** | **0.09** | **16.43** | **0.03** | **-** | **17.13** | **-** | **-** | **-** | **-** | **-** | **-** | **1.97** | **-** | **-** | **-** | **-** |
| Road | 0.09 | 16.43 | - | - | 16.68 | - | - | - | - | - | - | 1.97 | - | - | - | - |
| Domestic aviation | - | - | 0.03 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Rail | - | - | - | - | 0.39 | - | - | - | - | - | - | - | - | - | - | - |
| Pipeline transport | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Domestic navigation | - | - | - | - | 0.06 | - | - | - | - | - | - | - | - | - | - | - |
| Non-specified (transport) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Other** | **0.65** | **0.04** | **-** | **0.01** | **0.35** | **0.18** | **-** | **-** | **-** | **-** | **-** | **30.65** | **-** | **-** | **20.14** | **-** |
| Residential | 0.64 | - | - | 0.01 | - | - | - | - | - | - | - | 27.72 | - | - | 19.80 | - |
| Commercial | 0.01 | - | - | - | - | 0.18 | - | - | - | - | - | 2.87 | - | - | 0.34 | - |
| Agriculture | - | 0.04 | - | - | 0.35 | - | - | - | - | - | - | 0.06 | - | - | 0.0018 | - |
| Fishing | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Non-specified (other) | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| **Non-energy use** | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

As indicated in Figure 1, virtually all the AT* templates rely on the information in the EB_<region>(year) (in this case EB_Starter(2013)) workbook including the

- country or region name;
- fuel names and descriptions;
- emissions names, descriptions and rates;
- years the model is to be setup for (noting that TIMES supports model year and data year independence, so the model can be run for other years than those for which data is provided), and
- timeslice definitions and fractions apportioning the year into 4-seasons and 3-day slices (for a total of 12 divisions of the year) to track the timing of the electricity and (seasonal) heat demands.

Note that the milestone years and timeslice values in the TimePeriods&FRs sheet come from the LoadCalibration workbook. Both the SUP and the BY sector templates link to this sheet to get the year and timeslice information. Also, if the LoadCalibration workbook is updated, the years and timeslice information **MUST** be manually changed and the TimePeriods&FRs sheet is structured to allow the updated values to be copied and pasted into the BASE scenario of ANSWER, as shown in Figure 8.

## Figure 8: Years and Time Slice Data from the EB_Starter Workbook and in ANSWER

| Start year | Milestone Years | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2013 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |

**Pat DeLaquil:** If these values are to be changed, copy/paste them into the BASE scenario.

| | |
|---|---|
| Discount year (G_DYEAR) | 2015 |
| Global Discount rate (G_DRATE) | 0.05 |

**Annual Time Slices**

| | Spring | Spring Day | Spring night | Spring Peak | Summer | Summer Day | Summer Night | Summer Peak | Winter | Winter Day | Winter Night | Winter Peak | Fall | Fall Day | Fall Night | Fall Peak |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TimeSlice | SP | SPD | SPN | SPP | SU | SUD | SUN | SUP | WI | WID | WIN | WIP | FA | FAD | FAN | FAP |
| Year fraction (G_YRFR) | 0.251 | 0.147 | 0.084 | 0.021 | 0.251 | 0.147 | 0.084 | 0.021 | 0.246 | 0.143 | 0.082 | 0.021 | 0.251 | 0.148 | 0.083 | 0.021 |

Time slice inputs and sectoral FR inputs come from the Starter_Load Calibration template.

**Pat DeLaquil:** If Load calcibration is adjusted or G_YRFR are changed, copy/paste these values into the BASE scenario.

| TimeSlice | G_YRFR |
|---|---|
| FA | 0.2515 |
| FAD | 0.1479 |
| FAN | 0.0829 |
| FAP | 0.0207 |
| SP | 0.2513 |
| SPD | 0.1466 |
| SPN | 0.0838 |
| SPP | 0.0209 |
| SU | 0.2513 |
| SUD | 0.1466 |
| WI | 0.2459 |
| WID | 0.1434 |
| WIN | 0.0820 |
| WIP | 0.0205 |

**Sectoral Demand Load fractions (COM_FR)**

| Sector | SPD | SPN | SPP | SUD | SUN | SUP | WID | WIN | WIP | FAD | FAN | FAP | Check if 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Agriculture** | 0.200 | 0.026 | 0.024 | 0.300 | 0.154 | 0.046 | 0.000 | 0.000 | 0.000 | 0.200 | 0.026 | 0.024 | 1.000 |
| **Industry** | 0.147 | 0.084 | 0.021 | 0.147 | 0.084 | 0.021 | 0.143 | 0.082 | 0.021 | 0.148 | 0.083 | 0.021 | 1.000 |
| **Transport** | 0.147 | 0.084 | 0.021 | 0.147 | 0.084 | 0.021 | 0.143 | 0.082 | 0.021 | 0.148 | 0.083 | 0.021 | 1.000 |
| **Commercial** | | | | | | | | | | | | | |
| Heating | 0.126 | 0.050 | 0.024 | 0.000 | 0.000 | 0.000 | 0.384 | 0.144 | 0.072 | 0.126 | 0.050 | 0.024 | 1.000 |
| Hot Water | 0.158 | 0.063 | 0.030 | 0.158 | 0.063 | 0.030 | 0.160 | 0.060 | 0.030 | 0.158 | 0.063 | 0.030 | 1.000 |
| Space Cooling | 0.158 | 0.063 | 0.030 | 0.315 | 0.125 | 0.060 | 0.000 | 0.000 | 0.000 | 0.158 | 0.063 | 0.030 | 1.000 |
| Lighting | 0.189 | 0.075 | 0.036 | 0.063 | 0.025 | 0.012 | 0.256 | 0.096 | 0.048 | 0.126 | 0.050 | 0.024 | 1.000 |
| Other | 0.158 | 0.063 | 0.030 | 0.158 | 0.063 | 0.030 | 0.192 | 0.072 | 0.036 | 0.126 | 0.050 | 0.024 | 1.000 |
| **Residential** | | | | | | | | | | | | | |
| Heating | 0.130 | 0.048 | 0.022 | 0.000 | 0.000 | 0.000 | 0.390 | 0.144 | 0.066 | 0.128 | 0.046 | 0.026 | 1.000 |
| Hot Water | 0.163 | 0.060 | 0.028 | 0.163 | 0.058 | 0.030 | 0.163 | 0.060 | 0.028 | 0.160 | 0.058 | 0.033 | 1.000 |
| Space Cooling | 0.160 | 0.060 | 0.030 | 0.325 | 0.115 | 0.060 | 0.000 | 0.000 | 0.000 | 0.160 | 0.058 | 0.033 | 1.000 |
| Lighting | 0.192 | 0.072 | 0.036 | 0.065 | 0.023 | 0.012 | 0.256 | 0.096 | 0.048 | 0.128 | 0.046 | 0.026 | 1.000 |
| Other | 0.160 | 0.060 | 0.030 | 0.163 | 0.058 | 0.030 | 0.192 | 0.072 | 0.036 | 0.128 | 0.046 | 0.026 | 1.000 |

SETUP | Energy Balance | Example IEA balance | TimePeriods & FRs | Definitions | Conversion factors ...

| Scenario | Parameter | | Region | Region2 | Item1 | Item2 | Item3 | Ite | Item5 | Item | I/E | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BASE | G_DRATE | ? | STARTER | - | - | _ | - | - | - | - | 0 | 0.0500 |

| Scenario | Parameter | | Region | Region2 | Item1 | Item2 | Item3 | Ite | Item5 | Item | Value |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BASE | G_DYEAR | ? | _GLOBAL | - | - | _ | - | - | - | - | 2,015.00 |
| BASE | G_YRFR | ? | STARTER | - | - | _ | - | - | FA | - | 0.2515 |
| BASE | G_YRFR | ? | STARTER | - | - | _ | - | - | FAD | - | 0.1479 |
| BASE | G_YRFR | ? | STARTER | - | - | _ | - | - | FAN | - | 0.0829 |
| BASE | G_YRFR | ? | STARTER | - | - | _ | - | - | FAP | - | 0.0207 |
| BASE | G_YRFR | ? | STARTER | - | - | _ | - | - | SP | - | 0.2513 |
| BASE | G_YRFR | ? | STARTER | - | - | _ | - | - | SPD | - | 0.1466 |
| BASE | G_YRFR | ? | STARTER | - | - | _ | - | - | SPN | - | 0.0838 |
| BASE | G_YRFR | ? | STARTER | - | - | _ | - | - | SPP | - | 0.0209 |
| BASE | G_YRFR | ? | STARTER | - | - | _ | - | - | SU | - | 0.2513 |
| BASE | G_YRFR | ? | STARTER | - | - | _ | - | - | SUD | - | 0.1466 |
| BASE | G_YRFR | ? | STARTER | - | - | _ | - | - | SUN | - | 0.0838 |
| BASE | G_YRFR | ? | STARTER | - | - | _ | - | - | SUP | - | 0.0209 |
| BASE | G_YRFR | ? | STARTER | - | - | _ | - | - | WI | - | 0.2459 |
| BASE | G_YRFR | ? | STARTER | - | - | _ | - | - | WID | - | 0.1434 |
| BASE | G_YRFR | ? | STARTER | - | - | _ | - | - | WIN | - | 0.0820 |
| BASE | G_YRFR | ? | STARTER | - | - | _ | - | - | WIP | - | 0.0205 |

The information from the Energy Balance is collected on the EB sheet in the SUP and BY sector templates, which in turn controls the default commodities on the SETUP sheet according to what is currently used in the region to avoid loading those commodities not needed in the energy system.

> Note that when a commodity not in the initial year energy balance is needed in the future, simply **BLANK OUT** (not deleted/erased) the 0 found in sector EB sheet, as shown in Figure 8 for COM (D5) --- this then activates said commodity on the SETUP sheet and creates the associated X<sect><fuel> sector delivery processes. For SUP both the source (import/export/domestic) and the total need to be blanked out.

## Figure 9: Sector EB and Commodity Control Sheet

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | start year | 2013 | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | | |
| 3 | | | COAANT | COAOBC | COASBC | COALIG | COABKB | COAGWG | COAPEA | OILLPG | OILGSL | OILKER | OILDSL | OILFOI | OILNSO | GASNAT | BIOPSF | BIOGAS |
| 4 | PJ | Sector Name | Anthracite (Hard Coal) | Bituminous (Brown Coal) | Sub-Bituminous Coal | Lignite | Briquettes | Town (Coal) Gas | Peat | LPG | Gasoline | Kerosene | Diesel | Fuel Oil | Other Oil Products (excluding non-energy uses) | Natural Gas | Primary Solid Biofuels | Biogases |
| 5 | Commercial | COM | 0.013 | 0 | 0 | 0.0053 | 0 | 0 | 0 | 0.0134 | 0 | 0 | 0 | 0.1794 | 0 | 2.8712 | 0.336 | 0 |
| 6 | | | | | | | | | | | | | | | | | | |
| 7 | Split each by end-use | | | | | | | | | | | | | | | | | |
| 8 | CH | Commercial Heating | 100% | | | 100% | | | | | | | | 50% | | 60% | 100% | |
| 9 | CC | Commercial Cooling | | | | | | | | | | | | | | 1% | | |
| 10 | CWH | Commercial Water Heating | | | | | | | | | | | | 40% | | 16% | | |
| 11 | CCK | Commercial Cooking | | | | | | | | 100% | | | | | | 20% | | |
| 12 | CLT | Commercial Lighting | | | | | | | | | | | | | | | | |
| 13 | CRF | Commercial Refrigeration | | | | | | | | | | | | | | | | |
| 14 | COF | Commercial Office Equipment | | | | | | | | | | | | | | | | |
| 15 | CPL | Commercial Public Lighting | | | | | | | | | | | | | | | | |
| 16 | CME | Commercial Misc Energy | | | | | | | | | | | | 10% | | 3% | | |
| 17 | | **Check 100%** | **100%** | **0%** | **0%** | **100%** | **0%** | **0%** | **0%** | **100%** | **0%** | **0%** | **0%** | **100%** | **0%** | **100%** | **100%** | **0%** |
| 18 | | | | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | | | | |
| 20 | FEC by end-use | | | | | | | | | | | | | | | | | |
| 21 | CH | Commercial Heating | 0.013 | 0 | 0 | 0.0053 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0897 | 0 | 1.72272 | 0.336 | 0 |
| 22 | CC | Commercial Cooling | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.028712 | 0 | 0 |
| 23 | CWH | Commercial Water Heating | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.07176 | 0 | 0.459392 | 0 | 0 |
| 24 | CCK | Commercial Cooking | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0134 | 0 | 0 | 0 | 0 | 0 | 0.57424 | 0 | 0 |
| 25 | CLT | Commercial Lighting | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 26 | CRF | Commercial Refrigeration | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | COF | Commercial Office Equipment | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 28 | CPL | Commercial Public Lighting | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 29 | CME | Commercial Misc Energy | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.01794 | 0 | 0.086136 | 0 | 0 |
| 30 | | **Total** | **0.013** | **0** | **0** | **0.0053** | **0** | **0** | **0** | **0.0134** | **0** | **0** | **0** | **0.1794** | **0** | **2.8712** | **0.336** | **0** |
| 31 | | Check diff from FEC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Pat DeLaquil:**
If a fuel is needed for new planned or envisioned technologies, delete the existing zero entry to allow the X process to be created.
The matching supply must be activated similarly in the SUP

## 5.2 Supply

The Supply (SUP) sector of the TIMES-Starter has been setup with the basic imports, exports and domestic production for those energy carriers needed to supply the fuels currently consumed by the TIMES-Starter technologies in the database and in accordance with the first year Energy Balance. As mentioned in Section 5.1, the EB sheet in the SUP workbook connects to the EB workbook and is then used to control the fuels and supply options that are activated. If a new technology requires a fuel not in the current Energy Balance the 0 in rows 5 and 6-8 (as appropriate for domestic/imports/exports) of the SUP EB sheet should simply be deleted to activate said fuel for future use. The list of current energy carriers is shown in Figure 10.

## Figure 10: Current Supply Energy Carriers[9]

| Name | Region | Description |
|---|---|---|
| SUPBIOCHA | STARTER | Renewables - Charcoal |
| SUPBIODSL | STARTER | Renewables - Biodiesels |
| SUPBIOGAS | STARTER | Renewables - Biogases |
| SUPBIOGSL | STARTER | Renewables - Biogasoline |
| SUPBIOIWA | STARTER | Renewables - Industrial Waste |
| SUPBIOJKE | STARTER | Renewables - Bio Jet Kerosene |
| SUPBIOMSW | STARTER | Renewables - Municipal Waste |
| SUPBIOPSF | STARTER | Renewables - Primary Solid Biofuels |
| SUPCOAANT | STARTER | Coal - Anthracite |
| SUPCOABFG | STARTER | Coal - Blast Furnace Gas |
| SUPCOABKB | STARTER | Coal - Briquettes |
| SUPCOACCO | STARTER | Coal - Coking Coal |
| SUPCOACOG | STARTER | Coal - Coke Oven Gas |
| SUPCOAGCO | STARTER | Coal - Gas Coke |
| SUPCOAGWG | STARTER | Coal - Gas Works Gas |
| SUPCOALIG | STARTER | Coal - Lignite |
| SUPCOAOBC | STARTER | Coal - Other Bituminous Coal |
| SUPCOAORG | STARTER | Coal - Other Recovered Gases |
| SUPCOAPEA | STARTER | Coal - Peat |
| SUPCOASBC | STARTER | Coal - Sub-Bituminous Coal |
| SUPGASNAT | STARTER | Natural Gas: Supply |
| SUPGASPIP | STARTER | Natural Gas: Pipeline |
| SUPNUCLER | STARTER | Nuclear: Supply |

| Name | Region | Description |
|---|---|---|
| SUPOILASP | STARTER | Asphalt |
| SUPOILBIT | STARTER | Oil - Bitumen |
| SUPOILCOI | STARTER | Oil - Crude Oil |
| SUPOILDSL | STARTER | Oil - Diesel |
| SUPOILDST | STARTER | Distillate |
| SUPOILETH | STARTER | Oil - Ethane |
| SUPOILFOI | STARTER | Oil - Fuel Oil |
| SUPOILGSL | STARTER | Oil - Gasoline |
| SUPOILJET | STARTER | Oil - Jet Fuel |
| SUPOILJTF | STARTER | Jet Fuel |
| SUPOILKER | STARTER | Oil - Kerosene |
| SUPOILLPG | STARTER | Oil - LPG |
| SUPOILLUB | STARTER | Oil - Lubricants |
| SUPOILNAP | STARTER | Oil - Naphtha |
| SUPOILNGL | STARTER | Oil - Natural Gas Liquids |
| SUPOILNSO | STARTER | Oil - Non-specified Oil Products |
| SUPOILPCO | STARTER | Oil - Petroleum Coke |
| SUPOILPFS | STARTER | Petrochemical Feedstocks |
| SUPOILPTC | STARTER | Petroleum Coke |
| SUPOILRFE | STARTER | Oil - Refinery Feedstocks |
| SUPOILRFO | STARTER | Residual |
| SUPRNWETH | STARTER | Ethanol - Supply |
| SUPRNWGEO | STARTER | Renewables - Geothermal |
| SUPRNWH2 | STARTER | Hydrogen - Supply |
| SUPRNWHYD | STARTER | Renewables - Hydro |
| SUPRNWSOL | STARTER | Renewables - Solar |
| SUPRNWTWO | STARTER | Renewables - Tide, Wave and Ocean |
| SUPRNWWIN | STARTER | Renewables - Wind |

[9] This list encompasses all the energy forms listed in the standard IEA Energy Balance. However, currently there may not be technologies that produce/consume some of those listed.

For each SUP<core><type> fuel there needs to be a corresponding IMP-EXP/MIN<energy carrier> process that either takes imports from or sends exports to the IMPEXP region, or produces domestic resources from the MINRNW region respectively, with the current list of resource supply options listed in Figure 11.

**Figure 11: Imports & Domestic Resources Supply Options**

| Name | Region | Description |
|---|---|---|
| EXPSUPCOASBC-1 | STARTER | Export Coal - Sub-Bituminous Coal |
| IMPSUPCOAANT-1 | STARTER | Import Coal - Anthracite |
| IMPSUPCOABKB-1 | STARTER | Import Coal - Briquettes |
| IMPSUPCOACCO-1 | STARTER | Import Coal - Coking Coal |
| IMPSUPCOALIG-1 | STARTER | Import Coal - Lignite |
| IMPSUPCOASBC-1 | STARTER | Import Coal - Sub-Bituminous Coal |
| IMPSUPGASNAT-1 | STARTER | Import Natural Gas: Supply |
| IMPSUPNUCLER-1 | STARTER | Import Nuclear: Supply |
| IMPSUPOILCOI-1 | STARTER | Import Oil - Crude Oil |
| IMPSUPOILDSL-1 | STARTER | Import Oil - Diesel |
| IMPSUPOILFOI-1 | STARTER | Import Oil - Fuel Oil |
| IMPSUPOILGSL-1 | STARTER | Import Oil - Gasoline |
| IMPSUPOILJET-1 | STARTER | Import Oil - Jet Fuel |
| IMPSUPOILKER-1 | STARTER | Import Oil - Kerosene |
| IMPSUPOILLPG-1 | STARTER | Import Oil - LPG |
| IMPSUPOILNGL-1 | STARTER | Import Oil - Natural Gas Liquids |
| MINSUPCOALIG-1 | STARTER | Extraction Coal - Lignite |
| MINSUPCOASBC-1 | STARTER | Extraction Coal - Sub-Bituminous Coal |
| MINSUPGASNAT-1 | STARTER | Extraction Natural Gas: Supply |
| MINSUPOILCOI-1 | STARTER | Extraction Oil - Crude Oil |
| RNWSUPBIODSL-1 | STARTER | Renewables - Biodiesels |
| RNWSUPBIOGAS-1 | STARTER | Renewables - Biogases |
| RNWSUPBIOGSL-1 | STARTER | Renewables - Biogasoline |
| RNWSUPBIOIWA-1 | STARTER | Renewables - Industrial Waste |
| RNWSUPBIOJKE-1 | STARTER | Renewables - Bio Jet Kerosene |
| RNWSUPBIOMSW-1 | STARTER | Renewables - Municipal Waste |
| RNWSUPBIOPSF-1 | STARTER | Renewables - Primary Solid Biofuels |
| RNWSUPRNWGEO-1 | STARTER | Renewables - Geothermal |
| RNWSUPRNWHYD-1 | STARTER | Renewables - Hydro |
| RNWSUPRNWSOL-1 | STARTER | Renewables - Solar |
| RNWSUPRNWTWO-1 | STARTER | Renewables - Tide, Wave and Ocean |
| RNWSUPRNWWIN-1 | STARTER | Renewables - Wind |

The Supply template uses the earlier v1 of the ANSWER-TIMES templates, as the IRE parameters are not (yet) available in the newer v2, employed for most of the other templates, so it has a slightly different layout. The most important differences are:

- there is a single ITEMS sheet for commodities, processes, and user constraint declaration;
- there are different data load sheets depending upon the nature of the information to be handled;
- the parameters run down the rows rather than across the columns, and
- to the right of the I/E column the individual columns are taken in the order that the periods are handled in ANSWER *** Regardless of the header on Row-7 ***.

The SETUP sheet in the Supply template operates similarly to the other templates with one additional wrinkle. As shown in Figure 12 and discussed below, the user may provide factors that are applied to the assumed price for the various energy supply options and to the initial year supply to set the final period limit – linearly interpolated.

## Figure 12: Supply Template SETUP Sheet Price/Bound Factors

| A | B | C | D | E |
|---|---|---|---|---|
| | RNW | Renewable | | |
| * Source / Price Step | | | | |
| | -1 | | | |
| | -2 | new | | |
| * Imports | | | | |
| * Electricity & Heat | | | Price factor | Bound factor |
| | IMPELCT-1 | Import Electricity: Transmission | 1 | 1.2 |
| | GRD-ELCD-1 | Electricity: Distribution | | 1 |
| | GRD-LTHC-1 | Low-temperature Heat: Central | | 1 |
| | GRD-ELCD-2 | Electricity: Distribution - new | | nolim |
| | GRD-LTHC-2 | Low-temperature Heat: Central - new | | nolim |
| *Coal | | | | |
| | IMPSUPCOAANT-1 | Import Supply - Anthracite (Hard Coal) | 1 | 1.5 |
| * | IMPSUPCOACCO-1 | Import Supply - Metalurgical (Coking Coal) | 1 | 1 |
| | IMPSUPCOAOBC-1 | Import Supply - Bituminous (Brown Coal) | 1 | nolim |
| | IMPSUPCOASBC-1 | Import Supply - Sub-Bituminous Coal | 1 | 1 |
| | IMPSUPCOALIG-1 | Import Supply - Lignite | 0.85 | 1 |
| * | IMPSUPCOAGCO-1 | Import Supply - Coke | 1 | 1 |
| * | IMPSUPCOABKB-1 | Import Supply - Briquettes | 1.1 | 1 |
| * | IMPSUPCOAGWG-1 | Import Supply - Town (Coal) Gas | 1 | 1 |
| * | IMPSUPCOACOG-1 | Import Supply - Coke Oven Gas | 1 | 1 |
| * | IMPSUPCOABFG-1 | Import Supply - Blast Furnace Gas | 1 | 1 |
| | IMPSUPCOAORG-1 | Import Supply - Other coal product | 1 | nolim |
| * | IMPSUPCOAPEA-1 | Import Supply - Peat | 1 | 1 |
| * Oil | | | 1 | |
| * | IMPSUPOILCOI-1 | Import Supply - Crude Oil | 1.1 | 1 |
| * | IMPSUPOILNGL-1 | Import Supply - Natural Gas Liquids | 1.1 | 1 |

**Gary:**
IRE multipler for EPA or other IRE (if blue) - if blank need to set price on SupplyPrice sheet manually.

The commodity and process names, descriptions, units, and set memberships are entered on the ITEMS sheet, as in Figure 13. Note that the regions in Col-A need to align according to the nature of the possible supply sources.

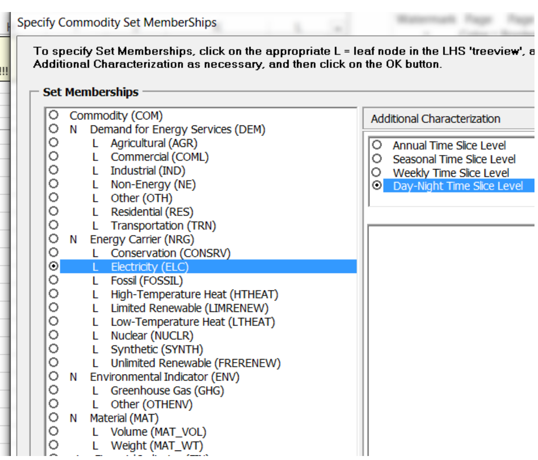
## Figure 13: Supply Items Declaration Sheet, and Set Membership Specification Form

ITEMS _GLOBAL,IMPEXP,MINRNW,STARTER

Check Sheet | Component | Unit(s) | Set Memberships

**Gary:**
If a commodity or process that has a region designation in col-A is NOT to be included in the model then make sure to move the reginoal specification to the next appropriate line!!!

| A | Comp | Name | Description | Unit(s) | Set Memberships | Comment |
|---|---|---|---|---|---|---|
| * COMMODITIES | | | | | | |
| * Energy Carriers | | | | | | |
| * Electricity & Heat | | | | | | |
| IMPEXP, STARTER | E | ELCT | Electricity: Transmission | PJ | COM,NRG,DAYNITE,ELC | |
| STARTER | E | ELCD | Electricity: Distribution | PJ | COM,NRG,DAYNITE,ELC | |
| STARTER | E | LTHC | Low-temperature Heat: Central | PJ | COM,NRG,SEASON,LTHEAT | |
| STARTER | E | LTH | Low-temperature Heat: Distribution | PJ | COM,NRG,SEASON,LTHEAT | |
| *Coal | | | | | | |
| IMPEXP,MINRNW, S | E | SUPCOAANT | Supply - Anthracite (Hard Coal) | PJ | COM,NRG,ANNUAL,FOSSIL | |
| * | E | SUPCOACCO | Supply - Metalurgical (Coking Coal) | PJ | COM,NRG,ANNUAL,FOSSIL | |
| IMPEXP,MINRNW, S | E | SUPCOAOBC | Supply - Bituminous (Brown Coal) | PJ | COM,NRG,ANNUAL,FOSSIL | |
| IMPEXP,MINRNW, S | E | SUPCOASBC | Supply - Sub-Bituminous Coal | PJ | COM,NRG,ANNUAL,FOSSIL | |
| IMPEXP,MINRNW, S | E | SUPCOALIG | Supply - Lignite | PJ | COM,NRG,ANNUAL,FOSSIL | |
| * | E | SUPCOAGCO | Supply - Coke | PJ | COM,NRG,ANNUAL,FOSSIL | |
| * | E | SUPCOABKB | Supply - Briquettes | PJ | COM,NRG,ANNUAL,FOSSIL | |
| * | E | SUPCOAGWG | Supply - Town (Coal) Gas | PJ | COM,NRG,ANNUAL,FOSSIL | |
| * | E | SUPCOACOG | Supply - Coke Oven Gas | PJ | COM,NRG,ANNUAL,FOSSIL | |
| * | E | SUPCOABFG | Supply - Blast Furnace Gas | PJ | COM,NRG,ANNUAL,FOSSIL | |
| IMPEXP,MINRNW, S | E | SUPCOAORG | Supply - Other coal product | PJ | COM,NRG,ANNUAL,FOSSIL | |




After the commodities (energy carriers and emissions) are declared (on the ITEMS sheet according to SETUP), the topology information needs to be provided on the TOP-TIDData sheet (via TOP_IRE indicators), and the main commodity delivered identified on the CommSup-TID_Data sheet (via PRC_ACTUNT), as shown in Figure 14.

## Figure 14: Supply Options Topology and Product

| TID TRADE | IMPEXP,MINRNW,STARTER | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Check Sheet | | | | | | | | | |
| | | Paramet | Arg1 | Arg2 | A | A | A | Arg6 | |
| Source / Dest Region | Internal Region | Topology Parameter | IRE Process | Source Commodity | n/a | n/a | n/a | Internal Commodity | Set IRE |
| * On TID TRADE sheet, a single region must be specified in column A (a comma-separated region- | | | | | | | | | |
| * Resource Supply Options | | | | | | | | | |
| * Imports | | | | | | | | | |
| * Electricity & Heat | | | | | | | | | |
| IMPEXP | STARTER | TOP_IRE | IMPELCT-1 | ELCT | - | - | - | ELCT | 1 |
| *Coal | | | | | | | | | |
| IMPEXP | STARTER | TOP_IRE | IMPSUPCOAANT-1 | SUPCOAANT | - | - | - | SUPCOAANT | 1 |
| * | STARTER | TOP_IRE | IMPSUPCOACCO-1 | SUPCOACCO | - | - | - | SUPCOACCO | 1 |
| IMPEXP | STARTER | TOP_IRE | IMPSUPCOAOBC-1 | SUPCOAOBC | - | - | - | SUPCOAOBC | 1 |
| IMPEXP | STARTER | TOP_IRE | IMPSUPCOASBC-1 | SUPCOASBC | - | - | - | SUPCOASBC | 1 |
| IMPEXP | STARTER | TOP_IRE | IMPSUPCOALIG-1 | SUPCOALIG | - | - | - | SUPCOALIG | 1 |
| * | STARTER | TOP_IRE | IMPSUPCOAGCO-1 | SUPCOAGCO | - | - | - | SUPCOAGCO | 1 |
| * | STARTER | TOP_IRE | IMPSUPCOABKB-1 | SUPCOABKB | - | - | - | SUPCOABKB | 1 |
| * | STARTER | TOP_IRE | IMPSUPCOAGWG-1 | SUPCOAGWG | - | - | - | SUPCOAGWG | 1 |
| * | STARTER | TOP_IRE | IMPSUPCOACOG-1 | SUPCOACOG | - | - | - | SUPCOACOG | 1 |
| * | STARTER | TOP_IRE | IMPSUPCOABFG-1 | SUPCOABFG | - | - | - | SUPCOABFG | 1 |
| IMPEXP | STARTER | TOP_IRE | IMPSUPCOAORG-1 | SUPCOAORG | - | - | - | SUPCOAORG | 1 |
| * | STARTER | TOP_IRE | IMPSUPCOAPEA-1 | SUPCOAPEA | - | - | - | SUPCOAPEA | 1 |
| * Oil | | | | | | | | | |
| * | STARTER | TOP_IRE | IMPSUPOILCOI-1 | SUPOILCOI | - | - | - | SUPOILCOI | 1 |
| * | STARTER | TOP_IRE | IMPSUPOILNGL-1 | SUPOILNGL | - | - | - | SUPOILNGL | 1 |
| * | STARTER | TOP_IRE | IMPSUPOILRFE-1 | SUPOILRFE | - | - | - | SUPOILRFE | 1 |
| * | STARTER | TOP_IRE | IMPSUPOILETH-1 | SUPOILETH | - | - | - | SUPOILETH | 1 |
| IMPEXP | STARTER | TOP_IRE | IMPSUPOILLPG-1 | SUPOILLPG | - | - | - | SUPOILLPG | 1 |
| IMPEXP | STARTER | TOP_IRE | IMPSUPOILGSL-1 | SUPOILGSL | - | - | - | SUPOILGSL | 1 |

... SETUP | EB | REGIONS | ITEMS | TOP_IRE-TIDData | Supply-TID DATA

| TID DATA | IMPEXP,MINRNW,STARTER | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Check Sheet | | | | | | | | |
| | Parameter | Arg1 | A | Arg3 | Ar | Ar | Arg6 | |
| Regions | Parameter | IRE Process | n/a | Commodity | n/a | n/a | n/a | Value |
| * Resource Supply Options | | | | | | | | |
| * Imports | | | | | | | | |
| * Electricity & Heat | | | | | | | | |
| IMPEXP,STARTER | PRC_ACTUNT | IMPELCT-1 | - | ELCT | - | - | - | 1 |
| *Coal | | | | | | | | |
| IMPEXP,STARTER | PRC_ACTUNT | IMPSUPCOAANT-1 | - | SUPCOAANT | - | - | - | 1 |
| *,STARTER | PRC_ACTUNT | IMPSUPCOACCO-1 | - | SUPCOACCO | - | - | - | 1 |
| IMPEXP,STARTER | PRC_ACTUNT | IMPSUPCOAOBC-1 | - | SUPCOAOBC | - | - | - | 1 |
| IMPEXP,STARTER | PRC_ACTUNT | IMPSUPCOASBC-1 | - | SUPCOASBC | - | - | - | 1 |
| IMPEXP,STARTER | PRC_ACTUNT | IMPSUPCOALIG-1 | - | SUPCOALIG | - | - | - | 1 |
| *,STARTER | PRC_ACTUNT | IMPSUPCOAGCO-1 | - | SUPCOAGCO | - | - | - | 1 |
| *,STARTER | PRC_ACTUNT | IMPSUPCOABKB-1 | - | SUPCOABKB | - | - | - | 1 |
| *,STARTER | PRC_ACTUNT | IMPSUPCOAGWG-1 | - | SUPCOAGWG | - | - | - | 1 |
| *,STARTER | PRC_ACTUNT | IMPSUPCOACOG-1 | - | SUPCOACOG | - | - | - | 1 |
| *,STARTER | PRC_ACTUNT | IMPSUPCOABFG-1 | - | SUPCOABFG | - | - | - | 1 |
| IMPEXP,STARTER | PRC_ACTUNT | IMPSUPCOAORG-1 | - | SUPCOAORG | - | - | - | 1 |
| *,STARTER | PRC_ACTUNT | IMPSUPCOAPEA-1 | - | SUPCOAPEA | - | - | - | 1 |
| * Oil | | | | | | | | |
| *,STARTER | PRC_ACTUNT | IMPSUPOILCOI-1 | - | SUPOILCOI | - | - | - | 1 |
| *,STARTER | PRC_ACTUNT | IMPSUPOILNGL-1 | - | SUPOILNGL | - | - | - | 1 |
| *,STARTER | PRC_ACTUNT | IMPSUPOILRFE-1 | - | SUPOILRFE | - | - | - | 1 |
| *,STARTER | PRC_ACTUNT | IMPSUPOILETH-1 | - | SUPOILETH | - | - | - | 1 |
| IMPEXP,STARTER | PRC_ACTUNT | IMPSUPOILLPG-1 | - | SUPOILLPG | - | - | - | 1 |
| IMPEXP,STARTER | PRC_ACTUNT | IMPSUPOILGSL-1 | - | SUPOILGSL | - | - | - | 1 |
| IMPEXP,STARTER | PRC_ACTUNT | IMPSUPOILJET-1 | - | SUPOILJET | - | - | - | 1 |
| IMPEXP,STARTER | PRC_ACTUNT | IMPSUPOILKER-1 | - | SUPOILKER | - | - | - | 1 |
| IMPEXP,STARTER | PRC_ACTUNT | IMPSUPOILDSL-1 | - | SUPOILDSL | - | - | - | 1 |

... SETUP | EB | REGIONS | ITEMS | TOP_IRE-TIDData | Supply-TID DATA

Data to be associated with the supply options is provided on Supply-TSData and Grid&Pipeline+BNDS sheet, most notably the resource supply costs and any limits (via IRE_PRICE/ACT_BND) for each supply step curve for each commodity, as appropriate. Figure 15 shows some sample prices. The prices are taken from the US-DOE EIA Annual Energy Outlook (AEO), with the user price factor from SETUP applied. Where the AEO does not provide data for a particular fuel, either adjustment factors from SETUP are applied to the price of a similar commodity or just placeholders provided where cells are colored according to:

- EPA = white or green, where green denotes the same EIA data used for >1 commodity;
- IRE = blue not in EIA price, but instead derived from another IRE;
- Other = yellow when pull from other sources, or
- Non-specified = red text, not yet setup - user to provide.

These prices are provided merely as a starting point to get the model running and behaving reasonably. The user needs to adjust the price information and update the potential limits over time for their situation. Furthermore, it may be the case that a particular commodity has more than one source (e.g., imports from different countries) and price (for example, less expensive open pit and more expensive mine coal). If this is the case then the entries for a similar supply option should be copied/inserted on the SETUP, Items, TOP_IRE, both Supply sheets as well as the BNDs sheet, incrementing the final character price index for each new supply source incremented (see rows 81-83 of the SETUP sheet). Note that with respect to both the price and bounds the user is free to drop the EIA-tied formulas and enter their data over the time horizon.

## Figure 15: Supply Options Prices

TS TRADE IMPEXP,MINRNW,STARTER

Check Sheet

Populate DataYears

Paramet Arg1 Arg2 Arg3 Arg5 Ar I/E Opt

**Color Key:**
SETUP(factor)*data, where data is:
- EPA = white or green, where green denotes the same EIA data use
- IRE = blue not in EIA price, but instead derived from another IRE
- Other = yellow when pull from other sources
- Non-specified = red text, not yet setup - user to provide

| Internal Region | Source/ Dest Region | Price Parameter | IRE Process | Commodity | Time slice | n/a | Import/ Export | n/a | I/E Opt | 2013 | 2015 | 2020 | 2025 | 2030 | 2035 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| * On TS TRADE sheet, a single region must be specified in column A (a comma-separated region-list is not allowed) | | | | | | | | | | | | | | | |
| * Resource Supply Options | | | | | | | | | | | | | | | |
| * Imports | | | | | | | | | | | | | | | |
| * Electricity & Heat | | | | | | | | | | | | | | | |
| STARTER | IMPEXP | IRE_PRICE | IMPELCT-1 | ELCT | ANNUAL | | IMP | | 0 | 36.04 | 36.30 | 37.13 | 37.07 | 38.18 | 39.34 |
| *Coal | | | | | | | | | | | | | | | |
| STARTER | IMPEXP | IRE_PRICE | IMPSUPCOAANT-1 | SUPCOAANT | ANNUAL | | IMP | | 0 | 2.47 | 2.54 | 2.91 | 3.11 | 3.34 | 3.52 |
| * | | IRE_PRICE | IMPSUPCOACCO-1 | SUPCOACCO | ANNUAL | | IMP | | 0 | 3.44 | 4.67 | 5.47 | 6.53 | 7.53 | 8.64 |
| STARTER | IMPEXP | IRE_PRICE | IMPSUPCOAOBC-1 | SUPCOAOBC | ANNUAL | | IMP | | 0 | 2.47 | 2.54 | 2.91 | 3.11 | 3.34 | 3.52 |
| STARTER | IMPEXP | IRE_PRICE | IMPSUPCOASBC-1 | SUPCOASBC | ANNUAL | | IMP | | 0 | 2.47 | 2.54 | 2.91 | 3.11 | 3.34 | 3.52 |
| STARTER | IMPEXP | IRE_PRICE | IMPSUPCOALIG-1 | SUPCOALIG | ANNUAL | | IMP | | 0 | 2.44 | 2.50 | 2.87 | 3.07 | 3.29 | 3.47 |
| * | | IRE_PRICE | IMPSUPCOAGCO-1 | SUPCOAGCO | ANNUAL | | IMP | | 0 | 11.60 | | | | | |
| * | | IRE_PRICE | IMPSUPCOABKB-1 | SUPCOABKB | ANNUAL | | IMP | | 0 | 3.16 | 3.24 | 3.72 | 3.97 | 4.26 | 4.50 |
| * | | IRE_PRICE | IMPSUPCOAGWG-1 | SUPCOAGWG | ANNUAL | | IMP | | 0 | 11.60 | | | | | |
| * | | IRE_PRICE | IMPSUPCOACOG-1 | SUPCOACOG | ANNUAL | | IMP | | 0 | 11.60 | | | | | |
| * | | IRE_PRICE | IMPSUPCOABFG-1 | SUPCOABFG | ANNUAL | | IMP | | 0 | 11.60 | | | | | |
| STARTER | IMPEXP | IRE_PRICE | IMPSUPCOAORG-1 | SUPCOAORG | ANNUAL | | IMP | | 0 | 11.60 | 11.60 | 11.60 | 11.60 | 11.60 | 11.60 |
| * | | IRE_PRICE | IMPSUPCOAPEA-1 | SUPCOAPEA | ANNUAL | | IMP | | 0 | 11.60 | | | | | |
| * Oil | | | | | | | | | | | | | | | |
| * | | IRE_PRICE | IMPSUPOILCOI-1 | SUPOILCOI | ANNUAL | | IMP | | 0 | 8.52 | 7.41 | 7.37 | 8.32 | 9.08 | 9.90 |
| * | | IRE_PRICE | IMPSUPOILNGL-1 | SUPOILNGL | ANNUAL | | IMP | | 0 | 8.58 | 10.35 | 11.30 | 12.31 | 13.54 | 14.88 |
| * | | IRE_PRICE | IMPSUPOILRFE-1 | SUPOILRFE | ANNUAL | | IMP | | 0 | 11.60 | | | | | |
| * | | IRE_PRICE | IMPSUPOILETH-1 | SUPOILETH | ANNUAL | | IMP | | 0 | 11.60 | | | | | |
| STARTER | IMPEXP | IRE_PRICE | IMPSUPOILLPG-1 | SUPOILLPG | ANNUAL | | IMP | | 0 | 8.60 | 10.37 | 11.33 | 12.34 | 13.57 | 14.91 |
| STARTER | IMPEXP | IRE_PRICE | IMPSUPOILGSL-1 | SUPOILGSL | ANNUAL | | IMP | | 0 | 38.03 | 32.99 | 31.96 | 34.19 | 35.64 | 37.98 |
| STARTER | IMPEXP | IRE_PRICE | IMPSUPOILJET-1 | SUPOILJET | ANNUAL | | IMP | | 0 | 28.72 | 23.81 | 24.32 | 27.43 | 29.62 | 32.27 |

... SETUP EB REGIONS ITEMS TOP_IRE-TIDData Supply-TID DATA SupplyPrice-TSData Grid&Pipelin ...

It is expected that all fuels can be found in the IEA energy balance needed for a country. However, if you do need to add a fuel, use a column that's not needed on the Energy Balance sheet of the EB workbook, which should then cascade into the Supply (and the BY workbooks --- REMEMBER to open/save all said EB dependent workbooks when making changes to the energy balance specfication.)

Note that any emissions that are to be associated with the energy carriers also need to be provided and their emission rate specified on a CommData sheet drawn from the EB workbook. The current template contains sector wide emissions accounting for fuel-based $CO_2$, CH4, and N2O. Provision for handling $SO_2$and NOx for other sectors and PM10 for the electric sector emissions could also be extracted from the US9r database, though is beyond the scope of the Starter model (currently).

Also, note that since the TIMES-Starter is (currently) a single region model there is no internal bi-lateral trade depicted.

## 5.3 Power Sector

### 5.3.1 Organization of the Power Sector Workbooks

This portion of the database resides in the BY/NT-PP workbooks, which contain several power plant process data sheets, as summarized in Table 4, along with their corresponding EPA-US9r and DEA data sheets. In addition, though not listed, as discussed in the introduction to this Section, the BY template includes an EB sheet tied to the EB workbook, both have a SETUP and Commodity/Process declaration sheets. The SETUP tab in the NT template is linked directly to the corresponding BY sheet for the commodity and plant type names to help ensure consistency. The final sheet (ProcData_XPRCs ) defines the sector fuel and emissions tracking processes (XPWR<fuel>) that link the supply commodities to the electric power sector, and is only found in the BY sheet. [If another new transmission line is needed it should be added to the SUP template with the appropriate start year (NCAP_START) and cost (NCAP_COST)].

The inclusion/exclusion and any adjustment to the names/descriptions of the technologies to be included in your TIMES model is fully controlled by the SETUP sheet for all the EPA/other plants from which data is taken. If you want to add additional plants, it is recommended that their names be built by copying/pasting a similar plant on SETUP, then adding a counter (or quality indicator) to the end of the name. The plant then needs to be added to Processes and the Non-EPA-PP (or other) ProcData loadsheets, either with data entered directly or by linking to a source data sheet (see the DEA plants/sheets for examples).

**Table 4: Data Sheets in Electricity Generation Technologies Workbook**

| Spreadsheet Name | Description |
|---|---|
| ProcData_NewPP | New power plant technologies using coal, gas, nuclear, biomass and geothermal. |
| ProcData_LFG&MSW | New power plant that use landfill gas or municipal solid waste. |
| ProcData_CHP | New combined heat & power plants. |
| ProcData_CCS | New coal & gas power plants with carbon sequestration, as well as existing plant retrofit options, and a "sink" to receive the sequestered $CO_2$. |
| ProcData_Solar&Wind | New solar & wind power plants. |
| ProcData_XPRCs | Sector fuel processes to move energy carriers from SUPply to PoWeR sector. [BY only] |

### 5.3.2 Electric Sector Naming Conventions and Units

In TIMES, electric generation technologies take in one or more fuels (energy carriers) and convert them to electricity for use by other processes and demand devices. Power plant capacity units are gigawatts (GW), and power plant investment and fixed operating and maintenance (O&M) costs are given in terms of monetary units per GW. Like all other energy carriers, the electricity produced is denominated in units of petajoules (PJ), and is related to the plant capacity through a conversion factor of 31.536 PJ/GW-yr. Variable O&M costs are thus expressed in monetary units per PJ.

The technologies represented in the power plant database range from fossil fuel conversion technologies to nuclear and renewable technologies, including combined heat and power plants, with options for (new) $CO_2$ capture and sequestration. The naming convention for electric generating technologies starts with ‘Ex’ where x=E for electricity and H for CHP or HP for heat-only plants, followed by a six-character identifier representing the fuel (energy carrier) type, and a two-character identifier representing the plant technology type as illustrated in Table 5, where “X0” for existing or “xx” for advanced and additional qualifiers where needed may be appended.

**Table 5: Electricity Generating Plant Type and Qualifiers**

| | | |
|---|---|---|
| * Plant Types | | |
| | EE | Electricity Generation |
| | EH | Coupled Heat & Power |
| | HP | Heating Plant |
| * Technology Types | | |
| | CC | Combined cycle |
| | CCS | CO2 Capture & Storage |
| | CP | CHP |
| | CT | Combustion turbine |
| | DM | Hydro (Dam) |
| | EN | Engine |
| | GT | Gas turbine |
| | IG | Integrated Gasif. |
| | LWR | LWR |
| | OF | Offshore |
| | ON | Onshore |
| * | PS | Hydro (Pumped Storage) |
| | PV | Photovoltaics |
| | RR | Hydro (Run-of-River) |
| | ST | Steam turbine |
| | TC | Thermal Central |
| | X0 | Existing |

Note that in terms of emission control no scrubber retrofits and only new $CO_2$ sequestration are implemented at this time.

### 5.3.3 Power Plant Technology Names and Descriptions

The EPA-US9r database is the primary source of data for the new electricity generation technologies, supplemented by the DEA CHP and HPL plants and low-temperature heat devices. This data will be augmented with data from other public sources over time, including but not limited to US DOE, IEA-ETSAP eTech-DS, IEA, and needed.

Table 6 lists the new electricity power plant options found in the database currently. Note that in the case of new hydroelectric plants they need to be characterized based upon local conditions, and therefore those in the NT template serve mainly as examples awaiting user input. Also, in US9r there are numerous instances of biomass, solar and wind, where data from a single region is used and only one wind class just now from the 1st instance encountered by the VLOOKUP --- but grabbing data from a US region more aligned with the country of study and/or adding additional wind classes can readily be done as desired. In general, the user needs to factor in local circumstance (e.g., land and labor costs) for all the power plant data provided.

### Table 6: New Power Plant Technologies

| | | | |
|---|---|---|---|
| * USDOE/EPA Technologies | | | |
| * Standard Power Plants | | | |
| | EECOAOBC-ST | Bituminous (Brown Coal) - Steam turbine | ECSTMRBONR |
| | EECOASBC-ST | Sub-Bituminous Coal - Steam turbine | ECSTMRSONR |
| | EECOALIG-ST | Lignite - Steam turbine | ECSTMRLONR |
| | EEGASNAT-CC | Natural Gas - Combined cycle | ENGACC15 |
| | EEGASNAT-CCA | Natural Gas - Combined cycle (Advanced) | ENGAACC |
| | EEGASNAT-CT | Natural Gas - Combustion turbine | ENGACT15 |
| | EEGASNAT-CTA | Natural Gas - Combustion turbine (Advanced) | ENGAACT |
| | EECOALIG-IG | Lignite - Integrated Gasif. Combined cycle | ECOALIGCC |
| | EENUCLER-LWR | Nuclear - LWR | EURNALWR15 |
| * LFG&MSW Plants | | | |
| | EEBIOGAS-EN | Biogases - Engine | ELFGICE |
| | EEBIOGAS-GT | Biogases - Gas turbine | ELFGGT |
| | EEBIOGAS-ST | Biogases - Steam turbine | ELFGST |
| | EEBIOGAS-CC | Biogases - Combined cycle | ELFGGCC |
| | EEBIOMSW-ST | Municipal Waste - Steam turbine | EMSWSTM |
| * Renewables Plants | | | |
| | EEBIOPSF-IG | Primary Solid Biofuels - Integrated Gasif. Combined | EBIOIGCC |
| | EERNWGEO-ST | Geothermal - Steam turbine | EGEOBCFS |
| | EERNWGEO-A | Geothermal (Advanced) | EGEOEGS |
| | EERNWSOL-PV4E | Solar - Photovoltaics: Class/CostCat 4E | ESOLPVC4E |
| | EERNWSOL-TC1E | Solar - Thermal Central: Class/CostCat 1E | ESOLSTCN1E |
| | EERNWWIN-ON3A | Wind - Onshore: Class/CostCat 3A | EWNDON3A |
| | EERNWWIN-ON3B | Wind - Onshore: Class/CostCat 3B | EWNDON3B |
| | EERNWWIN-ON3C | Wind - Onshore: Class/CostCat 3C | EWNDON3C |
| | EERNWWIN-ON3D | Wind - Onshore: Class/CostCat 3D | EWNDON3D |
| | EERNWHYD-DM | Hydro (Dam) | |
| * | EERNWHYD-PS | Hydro (Pumped Storage) | |
| | EERNWHYD-RR | Hydro (Run-of-River) | |
| * Danish Energy Agency Technologies | | | |
| * CHP Plants | | | DEA_CHP |
| | EHBIOPSF-ST | Coupled Heat & Power Primary Solid Biofuels - Stear | direct link |
| | EHCOAANT-ST | Coupled Heat & Power Anthracite (Hard Coal) - Stean | direct link |
| | EHGASNAT-CC | Coupled Heat & Power Natural Gas - Combined cycle | direct link |
| | EHGASNAT-EN | Coupled Heat & Power Natural Gas - Engine | direct link |
| * | EHOILFOI-CP | Fuel Oil - CHP | ECHPOIL |
| * District Heating Plants | | | DEA_DHP |

Also shown in Table 6 is the EPA technology name that is used for the VLOOKUP into the source data sheets, along with  the reminder that the DEA data is linked directly into their associated source data sheets.

> **Warning**: be sure to adhere to the basic naming convention of the components (that is use the same approach and number of characters as for some other entry) or the ANSWER named TechFilters and VBE Sets may no longer operate properly!

By default power plants are included if the commodity is part of the energy balance for the sector (including the removal of the base year 0 in the BY-PP EB sheet and needed in a later year, as discussed earlier) and the technology type is active (that is not “*” out explicitly by the user). Note that the plant and technology type in the BY template become the default in Col-A for inclusion/exclusion in the NT. Any power plant may be eliminated by entering “*”in Col-A on the SETUP sheet in either workbook. If there is a need to added a new power plant, do so by copying a similar type of plant’s name on the SETUP and Process declaration sheets, and then the data blocks on the appropriate ProcData_* sheet. Most of the names are carefully built from $references to their components, so after copying only minor adjustments need to be done to say change a fuel or technology instance. However, if adding a new technology there will be no corresponding data on the source data sheets, so the appropriate numbers will need to be provided, or linked if you have your own source data sheet that is included in the workbook. Also, be sure when adding an existing plant not yet in the database that the plant also gets added to the Calibration sheet appropriately (by copy/inserting a similar plant in the same group).

### 5.3.4 Power Plant Technology Data

The power plants are split into five groups by EPA: general (NewPP), landfill gas and municipal solid waste (LFG&MSW), combined heat & power (CHPs), other renewables (Solar&Wind), and carbon capture & storage (CCS). For each of these there are EPA_ and corresponding ProcData_ sheets, where the latter links to the former for the actual data by means of VLOOKUPs. The original EPA plant name is replicated (from the SETUP sheet) for use in the VLOOKUP. For the most part parameters are aligned and run across the workbook in the same order on the ProcData sheet as their associated source data sheets. However, there are exceptions, and the EPA data sheets are indexed to allow easier identification of the proper column index to use in the VLOOKUP expression. In addition, the cost parameters are converted to the local currency based upon the factor entered on the SETUP sheet, and the input oriented MARKAL efficiency inverted for the TIMES default output normalized equivalent.

A snapshot of a power sector ProcData loadsheet is shown in Figure 16. In the case of the DEA sheet (below) note that there is no TechLookUp column, reinforcing the fact that a non-EPA source data sheet is referenced by means of direct links to the source data sheet, as opposed to employing VLOOKUP.

## Figure 16: Power Sector New Plants Loadsheet

| Proc STARTER | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Check Sheet | ProcName, ProcDesc, Units | | CommIN | CommOUT | | * | | START | LIFE | CAPUNIT | PEAK(CON) | AF | FIXOM | VAROM | INP(ENT)c | INP(ENT)c | INP(ENT)c | INVCOST | INVCOST | INVCOST |
| Parameter | | | | | | | PRC_VINT | NCAP_STAR | NCAP_TLIF | PRC_CAPACT | NCAP_PKCNT | NCAP_AF-UP | NCAP_FOM | ACT_COST | ACT_EFF | ACT_EFF | ACT_EFF | NCAP_COST | NCAP_COST | NCAP_COST |
| Qualifier1 | | | | | | | | | | | ANNUAL | ANNUAL | | | ACTGRP | ACTGRP | ACTGRP | | | |
| Qualifier2 | | | | | | | | | | | | | | | ANNUAL | ANNUAL | ANNUAL | | | |
| ProcName | ProcDesc | ProcUnits | CommIN | CommOUT | ctiv | Tech Lookup | TID | TID | | TID | | | | | | 2020 | 2025 | | 2020 | 2025 |
| * Standard Power Plants | | | | | | | | | | | | | | | | | | | | |
| EECOAOBC-ST | Bituminous (Brown ( | PJ,GW | PWRCOAOBC | | | ECSTMRBONF | 1 | 2015 | 45 | 31.536 | 0.95 | 0.9 | 31.70 | 1.26 | 0.3877 | 0.3891 | 0.3904 | 2779.1617 | | |
| | | | | ELCT | | | | | | | | | | | | | | | | |
| EECOASBC-ST | Sub-Bituminous Co | PJ,GW | PWRCOASBC | | | ECSTMRSONF | 1 | 2015 | 45 | 31.536 | 0.95 | 0.9 | 31.70 | 1.26 | 0.3877 | 0.3891 | 0.3904 | 2779.1617 | | |
| | | | | ELCT | | | | | | | | | | | | | | | | |
| EEGASNAT-CC | Natural Gas - Combi | PJ,GW | PWRGASNAT | | | ENGACC15 | 1 | 2015 | 30 | 31.536 | 0.95 | 0.9 | 13.39 | 1.02 | 0.4840 | 0.4840 | 0.4840 | 885.3877 | 885.3877 | 885.3877 |
| | | | | ELCT | | | | | | | | | | | | | | | | |
| EEGASNAT-CC | Natural Gas - Combi | PJ,GW | PWRGASNAT | | | ENGAACC | 1 | 2020 | 30 | 31.536 | 0.95 | 0.9 | 15.62 | 0.92 | 0.5306 | 0.5347 | 0.5388 | 960.6100 | 929.3902 | 913.7803 |
| | | | | ELCT | | | | | | | | | | | | | | | | |
| EEGASNAT-CT | Natural Gas - Combu | PJ,GW | PWRGASNAT | | | ENGACT15 | 1 | 2015 | 30 | 31.536 | 0.95 | 0.9 | 7.46 | 4.36 | 0.3125 | 0.3125 | 0.3125 | 939.2631 | 939.2631 | 939.2631 |
| | | | | ELCT | | | | | | | | | | | | | | | | |
| EEGASNAT-CT | Natural Gas - Combu | PJ,GW | PWRGASNAT | | | ENGAACT | 1 | 2020 | 30 | 31.536 | 0.95 | 0.9 | 7.16 | 2.93 | 0.3499 | 0.3729 | 0.3991 | 651.5884 | 627.1538 | 614.9365 |
| | | | | ELCT | | | | | | | | | | | | | | | | |
| EECOALIG-IG | Lignite - Integrated ( | PJ,GW | PWRCOALIG | | | ECOALIGCC | 1 | 2015 | 40 | 31.536 | 0.95 | 0.9 | 52.24 | 2.04 | 0.3922 | 0.4225 | 0.4580 | 3583.2279 | 3443.4820 | 3373.6091 |
| | | | | ELCT | | | | | | | | | | | | | | | | |
| EENUCLER-LW | Nuclear - LWR | PJ,GW | PWRNUCLER | | | EURNALWR15 | 1 | 2015 | 45 | 31.536 | 0.95 | 0.9 | 94.82 | 0.60 | 0.3400 | 0.3400 | 0.3400 | 4841.6779 | 4599.5940 | 4478.5520 |
| | | | | ELCT | | | | | | | | | | | | | | | | |
| EECOALIG-ST | Lignite - Steam turbi | PJ,GW | PWRCOALIG | | | ECSTMRLONF | 1 | 2015 | 45 | 31.536 | 0.95 | 0.9 | 31.70 | 1.26 | 0.3877 | 0.3891 | 0.3904 | 2779.1617 | | |
| | | | | ELCT | | | | | | | | | | | | | | | | |

ANSv2-691-Home | SETUP | Commodities | Processes | ProcData_EPA-NewPP | ProcData_Non-EPA-PPs | ProcData_EPA-LF( ...

| Proc STARTER | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Check Sheet | ne, ProcDesc, Units | | CommIN | CommO | | * | | | | | | | | | |
| Parameter | | | | | | PRC_VINT | NCAP_STAR | P_TLIFE | AP_ILED | PRC_CAPAC | ACT_EFF | ACT_EFF | ACT_EFF | NCAP_COST | NCAP_CO |
| Qualifier1 | | | | | | | | | | | ACTGRP | ACTGRP | ACTGRP | | |
| Qualifier2 | | | | | | | | | | | ANNUAL | ANNUAL | ANNUAL | | |
| ProcName | ProcDesc | ProcUnits | CommIN | CommOUT | Activity I/O | TID | TID | | | TID | 2015 | 2030 | 2050 | 2015 | 2030 |
| * Danish Energy Agency Technologies | | | | | | | | | | | | | | | |
| EHBIOPSF-ST | Coupled Heat & Power Primary Solid Biofuel | PJ,GW | PWRBIOPSF | | | 1 | 2015 | 30 | -4.5 | 31.536 | 0.29 | 0.29 | 0.29 | 3340 | 3340 |
| | | | | ELCT | | | | | | | | | | | |
| | | | | LTHC | | | | | | | | | | | |
| EHCOAANT-ST | Coupled Heat & Power Anthracite (Hard Coa | PJ,GW | PWRCOAANT | | | 1 | 2015 | 40 | -4.5 | 31.536 | 0.44 | 0.52 | 0.53 | 2621 | 2557 |
| | | | | ELCT | | | | | | | | | | | |
| | | | | LTHC | | | | | | | | | | | |
| EHGASNAT-CC | Coupled Heat & Power Natural Gas - Combi | PJ,GW | PWRGASNAT | | | 1 | 2015 | 30 | -1.5 | 31.536 | 0.55 | 0.59 | 0.60 | 1118 | 1041 |
| | | | | ELCT | | | | | | | | | | | |
| | | | | LTHC | | | | | | | | | | | |
| EHGASNAT-EN | Coupled Heat & Power Natural Gas - Engine | PJ,GW | PWRGASNAT | | | 1 | 2015 | 25 | -1 | 31.536 | 0.45 | 0.49 | 0.50 | 1574 | 1574 |
| | | | | ELCT | | | | | | | | | | | |
| | | | | LTHC | | | | | | | | | | | |
| EHOILFOI-CP | Fuel Oil - CHP | PJ,GW | PWROILFOI | | | 1 | 2015 | 40 | -3 | 31.536 | 0.25 | 0.25 | 0.25 | 1127 | 1127 |
| * | | | | ELCT | | | | | | | | | | | |
| * | | | | LTHC | | | | | | | | | | | |

... | ProcData_EPA-CCS | ProcData_DEA-CHP | ProcData_DEA-HPL | EPA_Commodities | EPA_NewPP | EPA_LFG&M ...

Note that the vintage flag is set automatically if more than 1 efficiency is provided for a plant, that is if its performance is expected to improve over time.

### 5.3.5 Calibration of the Initial Year

The power sector needs to properly reflect the first year fuel consumption and generation levels, as well as the proper amount of installed capacity for each plant type. To do this the EB energy balance sheet is automatically filled from the EB workbook, with the Calibration sheet, Figure 17, completed by providing relevant information for the yellow shaded cells related to retirement year, existing capacity, fuel consumed, electricity generated, with the maximum availability and general overal efficiency derived from that information which may be overwritten by the user if desired.

### Figure 17: Power Sector Calibration Sheet

| Calibration of power and heat generation | Fuel | Decomissioning year | Existing Capacity | Fuel consumption | Electricity Produced | Base Year Capacity factor | Availability for future years | Efficiency | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Est/known | Est/known elc prod | Calc. from Elc and Cap | Max capacity factor AF | Based on elc:fuel ratio | Standard Estimate | Model input |
| er Plants | | | GW | PJ | PJ | % | % | % | % | % |
| Hydro (Dam) (Existing) | PWRRNWHYD | 2040 | 0.120 | 1.500 | 1.500 | 39.6% | 39.64% | 100.0% | 100.0% | 100.0% |
| Hydro (Run-of-River) (Existing) | PWRRNWHYD | 2050 | 0.050 | 0.50 | 0.500 | 31.7% | 31.71% | 100.0% | 100.0% | 100.0% |
| Hydro (Pumped Storage) (Existing) | PWRRNWHYD | 2040 | | | | - | 0.00% | - | | - |
| | PWRELC | | | | | | | | | |
| **Total** | | | **0.170** | **2.000** | **2.000** | | | | | |
| Natural Gas - Combined cycle (Existing) | PWRGASNAT | 2030 | 0.110 | 6.67 | 3.000 | 86.5% | 90.0% | 45.0% | 48.4% | 45.0% |
| Natural Gas - Combustion turbine (Existing) | PWRGASNAT | 2025 | 0.150 | 11.98 | 3.355 | 70.9% | 90.0% | 28.0% | 30.0% | 28.0% |
| **Total** | | | **0.260** | **18.650** | **6.355** | | | | | |
| Bituminous (Brown Coal) - Steam turbine (Existing) | PWRCOAOBC | 2025 | 0.060 | 4.59 | 1.500 | 79.3% | 90.0% | 32.7% | 38.8% | 32.7% |
| Sub-Bituminous Coal - Steam turbine (Existing) | PWRCOASBC | 2025 | 0.060 | 4.50 | 1.500 | 79.3% | 90.0% | 33.3% | 38.8% | 33.3% |
| Lignite - Steam turbine (Existing) | PWRCOALIG | 2030 | 0.200 | 13.64 | 4.500 | 71.3% | 90.0% | 33.0% | 38.8% | 33.0% |
| Lignite - Integrated Gasif. (Existing) Combined cycle | PWRCOALIG | 2040 | 0.120 | 8.57 | 3.000 | 79.3% | 90.0% | 35.0% | 39.2% | 35.0% |
| **Total** | | | **0.440** | **31.300** | **10.500** | | | | | |
| Nuclear - LWR (Existing) | PWRNUCLER | 2035 | 0.050 | 2.94 | 1.000 | 63.4% | 90.0% | 34.0% | 34.0% | 34.0% |
| **Total** | | | **0.050** | **2.940** | **1.000** | | | | | |
| Biogases - Engine (Existing) | PWRBIOGAS | 2025 | 0.020 | 1.47 | 0.50 | 79.3% | 90.0% | 34.0% | 36.0% | 34.0% |

... SETUP | EB | Calibration | Commodities | CommData | Processes | ProcData_EPA-StandardPP | ProcData_Non-EPA-PPs ...

Note that if for any fuel group the fuel consumption total does not match the Energy Balance an error message will be displayed in the cell about that fuel group with the difference from the EB sheet shown.

As discussed in more detail in Section 6, the work on the Calibration sheets in each BY workbook is the starting point for the calibration process. The cycle involves running the model (for just the first period if desired) and using the VBE calibration check workbook to see how well the model is aligning with the energy balance, returning to the BY Calibration sheets to refine plant capacity, consumption and production (and derived efficiency) assumptions as needed.

## 5.4 Demand Sectors

There are five (5) demand sectors in the TIMES-Starter:

- Agriculture;
- Commercial;
- Industry;
- Residential, and
- Transportation.

Each sector is contained in a separate pair of workbooks (BY/NT-<sect>) that are loaded into their corresponding scenarios in the TIMES-Starter database. Within each workbook the standard set of worksheets introduced earlier in Table 1 can be found. Unless otherwise noted, the demand for energy services is in petajoules (PJ).

### 5.4.1 Agriculture

The US9r model does not explicitly breakout the Agriculture sector. However, the Asian Development Bank Pakistan Integrated Energy Model project (Pak-IEM)[10] did breakout the agriculture sector into four services (Tractors, Irrigation, Other), with associated devices as shown in Figure 18.

**Figure 18: Agriculture New Processes[11]**

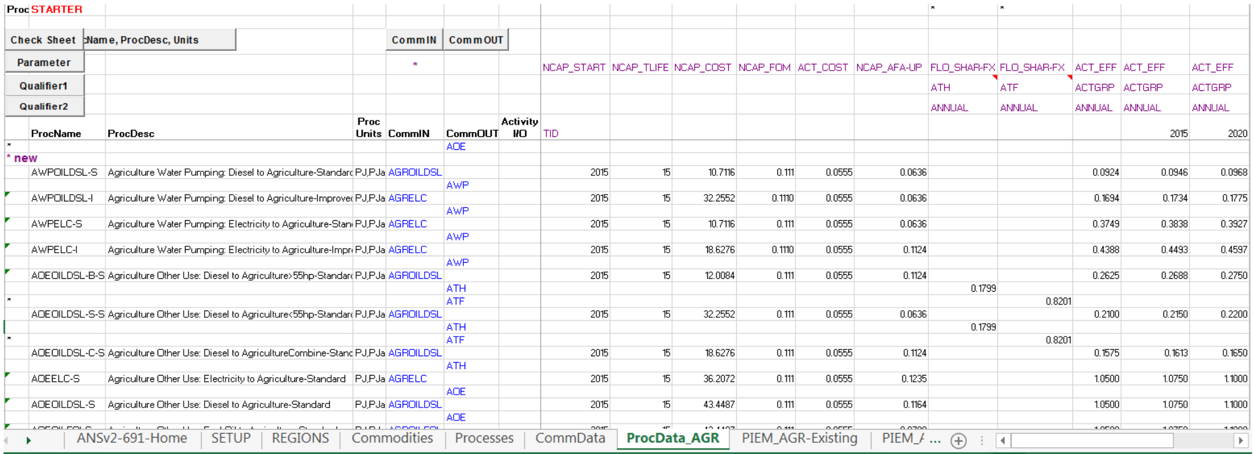
| | | |
|---|---|---|
| * **End-Use Services** | | |
| | AWP | Agriculture Water Pumping |
| | ATH | Agriculture Tractors - Hauling |
| * | ATF | Agriculture Tractors - Farm Op. |
| | AOE | Agriculture Other Use |
| * **Quality** | | |
| | -I | -Improved |
| | -S | -Standard |
| * **Tractor type** | | |
| | -B | >55hp |
| | -S | <55hp |
| | -C | Combine |
| * **TECHNOLOGIES** | | |
| * **Agriculture Water Pumping** | | |
| | AWPOILDSL-S | Agriculture Water Pumping: Diesel to Agriculture-Standard |
| | AWPOILDSL-I | Agriculture Water Pumping: Diesel to Agriculture-Improved |
| | AWPELC-S | Agriculture Water Pumping: Electricity to Agriculture-Standard |
| | AWPELC-I | Agriculture Water Pumping: Electricity to Agriculture-Improved |
| * **Agriculture Tractors - Hauling** | | |
| | ATHOILDSL-B-S | Agriculture Tractors - Hauling: Diesel to Agriculture>55hp-Standard |
| | ATHOILDSL-S-S | Agriculture Tractors - Hauling: Diesel to Agriculture<55hp-Standard |
| | ATHOILDSL-C-S | Agriculture Tractors - Hauling: Diesel to AgricultureCombine-Standard |
| * **Agriculture Tractors - Farm Op.** | | |
| * **Agriculture Other Use** | | |
| | AOEELC-S | Agriculture Other Use: Electricity to Agriculture-Standard |
| | AOEOILDSL-S | Agriculture Other Use: Diesel to Agriculture-Standard |
| * | AOEOILFOI-S | Agriculture Other Use: Fuel Oil to Agriculture-Standard |

Note that tractors are setup to be able to service separate demands for farm operations and haulage according to the FLO_SHARs, which may need to be adjusted for a particular country. However, only a single Tractors demand is currently specified in the Starter model. If the user wants to separate farm operation from hauling then the ATF end-use service simply has to be uncommented in Col-A of the SETUP sheet in the BY template , and the FLO_SHARs added on the ProcData sheet. Also, the demand projections will need to be provided for each of the two tractor demand services. A snapshot of the Agriculture load sheet is shown in Figure 19.

[10] http://www.decisionwaregroup.com/index.html - International page.

[11] Note that *Existing and *Vintage have been physically removed from the SETUP, Items and Data sheets to make them less cluttered and cleaner, though they are present on the US9r source data worksheets.

## Figure 19: Agriculture New Options Loadsheet



Proc STARTER

Check Sheet | cName, ProcDesc, Units | CommIN | CommOUT

| Parameter | | | | * | | | NCAP_START | NCAP_TLIFE | NCAP_COST | NCAP_FOM | ACT_COST | NCAP_AFA-UP | FLO_SHAR-FX | FLO_SHAR-FX | ACT_EFF | ACT_EFF | ACT_EFF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Qualifier1 | | | | | | | | | | | | | ATH | ATF | ACTGRP | ACTGRP | ACTGRP |
| Qualifier2 | | | | | | | | | | | | | ANNUAL | ANNUAL | ANNUAL | ANNUAL | ANNUAL |
| | ProcName | ProcDesc | Proc Units | CommIN | CommOUT | Activity I/O | TID | | | | | | | | | 2015 | 2020 |
| * | | | | | AOE | | | | | | | | | | | | |
| * new | | | | | | | | | | | | | | | | | |
| | AWPOILDSL-S | Agriculture Water Pumping: Diesel to Agriculture-Standarc | PJ,PJa | AGROILDSL | | | 2015 | 15 | 10.7116 | 0.111 | 0.0555 | 0.0636 | | | 0.0924 | 0.0946 | 0.0968 |
| | | | | | AWP | | | | | | | | | | | | |
| | AWPOILDSL-I | Agriculture Water Pumping: Diesel to Agriculture-Improvec | PJ,PJa | AGRELC | | | 2015 | 15 | 32.2552 | 0.1110 | 0.0555 | 0.0636 | | | 0.1694 | 0.1734 | 0.1775 |
| | | | | | AWP | | | | | | | | | | | | |
| | AWPELC-S | Agriculture Water Pumping: Electricity to Agriculture-Stan | PJ,PJa | AGRELC | | | 2015 | 15 | 10.7116 | 0.111 | 0.0555 | 0.0636 | | | 0.3749 | 0.3838 | 0.3927 |
| | | | | | AWP | | | | | | | | | | | | |
| | AWPELC-I | Agriculture Water Pumping: Electricity to Agriculture-Impr | PJ,PJa | AGRELC | | | 2015 | 15 | 18.6276 | 0.1110 | 0.0555 | 0.1124 | | | 0.4388 | 0.4493 | 0.4597 |
| | | | | | AWP | | | | | | | | | | | | |
| | AOEOILDSL-B-S | Agriculture Other Use: Diesel to Agriculture>55hp-Standarc | PJ,PJa | AGROILDSL | | | 2015 | 15 | 12.0084 | 0.111 | 0.0555 | 0.1124 | | | 0.2625 | 0.2688 | 0.2750 |
| | | | | | ATH | | | | | | | | 0.1799 | | | | |
| * | | | | | ATF | | | | | | | | | 0.8201 | | | |
| | AOEOILDSL-S-S | Agriculture Other Use: Diesel to Agriculture<55hp-Standarc | PJ,PJa | AGROILDSL | | | 2015 | 15 | 32.2552 | 0.111 | 0.0555 | 0.0636 | | | 0.2100 | 0.2150 | 0.2200 |
| | | | | | ATH | | | | | | | | 0.1799 | | | | |
| * | | | | | ATF | | | | | | | | | 0.8201 | | | |
| | AOEOILDSL-C-S | Agriculture Other Use: Diesel to AgricultureCombine-Stanc | PJ,PJa | AGROILDSL | | | 2015 | 15 | 18.6276 | 0.111 | 0.0555 | 0.1124 | | | 0.1575 | 0.1613 | 0.1650 |
| | | | | | ATH | | | | | | | | | | | | |
| | AOEELC-S | Agriculture Other Use: Electricity to Agriculture-Standard | PJ,PJa | AGRELC | | | 2015 | 15 | 36.2072 | 0.111 | 0.0555 | 0.1235 | | | 1.0500 | 1.0750 | 1.1000 |
| | | | | | AOE | | | | | | | | | | | | |
| | AOEOILDSL-S | Agriculture Other Use: Diesel to Agriculture-Standard | PJ,PJa | AGROILDSL | | | 2015 | 15 | 43.4487 | 0.111 | 0.0555 | 0.1164 | | | 1.0500 | 1.0750 | 1.1000 |
| | | | | | AOE | | | | | | | | | | | | |

ANSv2-691-Home | SETUP | REGIONS | Commodities | Processes | CommData | ProcData_AGR | PIEM_AGR-Existing | PIEM_/ ...

As already noted, the BY template includes an EB sheet tied to the EB workbook, both have a SETUP and Commodity/Process declaration sheets. The NT template SETUP tab is linked directly to the corresponding BY sheet for the commodity and device names to help ensure consistency. The final sheet (ProcData_XPRCs ) defines the sector fuel and emissions tracking processes (XAGR<fuel>) that link the supply commodities to the Agriculture sector, and is only found in the BY sheet. If new commodities not found in the original first year energy balance are needed for future years, as discussed in Section 6, the 0 on row-5 of the BY-AGR EB sheet for said fuel should be deleted, activating the fuel and associated XAGR<fuel> process.

Any Agriculture component may be eliminated by entering "*" in Col-A on the SETUP sheet. If there is a need to add a new device type, do so by copying a similar type of devices' name on SETUP then Process data blocks on the appropriate ProcData_* sheets. Most of the names are carefully built from $references to their components, so after copying only minor adjustments need to be done to, say, change a fuel or technology instance. However, if adding a new technology there will be no corresponding data on the source data sheets, so the appropriate numbers will need to be provided. Also, be sure when adding an existing device not yet in the database that the device also gets added to the Calibration sheet appropriately (by copy/inserting a similar device in the same group).

> **Warning**: be sure to adhere to the basic naming convention of the components (that is use the same approach and number of characters as for some other entry) or the ANSWER named TechFilters and VBE Sets may no long operate properly!

### 5.4.1.1 *Calibration of the Initial Year*

The agriculture sector is rather simplified with only demands for tractors, irrigation and other. Once fuels have been apportioned to those energy serices on the EB sheet the only other action required is to split the tractor demand between small and large tractors (or combines), as seen in Figure 20. When entering any of these device splits, when there is more than one competing device consuming the same fuel, shares are requested for all but one of them, with the remaining share calculated to ensure the service/fuel total is respected.

**Figure 20: Agriculture Calibration Sheet**

| | | | | | | |
|---|---|---|---|---|---|---|
| Agriculture Water Pumping | EFF | CF | FEC share | energy (PJ) | Energy (PJ) | Capacity (PJ/a) |
| Agriculture Water Pumping: Diesel to Agriculture- Existing | 0.09 | 0.06 | 1 | 0 | 0.0000 | 0.00 |
| Agriculture Water Pumping: Electricity to Agriculture- Exis | 0.36 | 0.11 | 1 | 0.1246 | 0.0445 | 0.40 |
| | | | | **0.1246** | **0.0445** | |
| | | | from EB | 0.1246 | | |
| | | | **check if zero** | **0.0000** | | |
| | | | | | | |
| | | | | Final | Useful | Installed |
| Agriculture Tractors | EFF | CF | FEC share | energy (PJ) | Energy (PJ) | Capacity (PJ/a) |
| Agriculture Tractors: Diesel to Agriculture>55hp- Existing | 0.25 | 0.12 | 0.3 | 0.10587 | 0.0265 | 0.21 |
| Agriculture Tractors: Diesel to Agriculture<55hp- Existing | 0.20 | 0.12 | 0.3 | 0.10587 | 0.0212 | 0.18 |
| Agriculture Tractors: Diesel to AgricultureCombine- Existi | 0.15 | 0.08 | 0.4 | 0.14116 | 0.0212 | 0.26 |
| | | | | **0.3529** | **0.0688** | |
| | | | from EB | 0.3529 | | |
| | | | **check if zero** | **0.0000** | | |
| | | | | | | |
| | | | | Final | Useful | Installed |
| Agriculture Other Use | EFF | CF | FEC share | energy (PJ) | Energy (PJ) | Capacity (PJ/a) |
| Agriculture Other Use: Electricity to Agriculture- Existing ( | 1.00 | 1.00 | 1 | 0 | 0.0000 | 0.00 |
| Agriculture Other Use: Diesel to Agriculture- Existing 00 | 1.00 | 1.00 | 1 | 0 | 0.0000 | 0.00 |
| Agriculture Other Use: Fuel Oil to Agriculture- Existing 00 | 1.00 | 1.00 | 1 | 0 | 0.0000 | 0.00 |
| | | | | **0.0000** | **0.0000** | |
| | | | from EB | 0.0588 | | |
| | | | **check if zero** | **0.0588** | | |

As discussed in Section 6, the work on the Calibration sheets in each BY workbook is the starting point for the calibration process. The cycle involves running the model (for just the first period if desired) and using the VBE calibration check workbook to see how well the model is aligning with the energy balance, returning to the BY Calibration sheets to device share assumptions as needed.

### 5.4.2 Commercial

The US9r Commercial sector demands are specified for the end-use applications listed in Figure 21, with each of these applications serviced by multiple (sometimes many) devices. In the case of heating/cooling, the Building type is appended to the demand root so that if additional building types are added they are properly distinguished in all the device names. As shown in the figure, there are various types of lighting applications, including CFLs, halogen, incandescent, LED, etc., with different wattage and vintages (year in which they become available). The situation is similar for the other sectors as well. As discussed in Section 10, these various lighting options need to be apportioned by the user according to the general situation in the area of study, otherwise the single most cost-effective option will dominate the service demand. The multiple vintages of a technology in the EPA MARKAL model are replaced by a single technology option by using the vintage feature in TIMES.

The Commercial sector is designed the same as the rest of the EPA US9r referenced templates, in that the SETUP sheet controls what is/is not included for the sector, and the ProcData_COM sheet links directly to its EPA_COM counterpart by means of VLOOKUP based upon the EPA device name grabbed from SETUP in Col-H. In the case of costs, they are converted according to the factor specified in the SETUP tab (inherited from the EB workbook). The names and descriptions employed are assembled on the SETUP sheet according to the components in Figure 21 combined with the commodity consumed.

**Figure 21: Commercial Sector End-use Applications & Lighting Technology Types**

**Building Type & End-Use Application**

| | | |
|---|---|---|
| * Sector Components | | |
| * Building Types | | |
| | B | |
| * Energy Services | | |
| | CH | Commercial Heating |
| | CC | Commercial Cooling |
| | CWH | Commercial Water Heating |
| | CCK | Commercial Cooking |
| | CLT | Commercial Lighting |
| | CRF | Commercial Refrigeration |
| | COF | Commercial Office Equipment |
| | CPL | Commercial Public Lighting |
| | CME | Commercial Misc Energy |

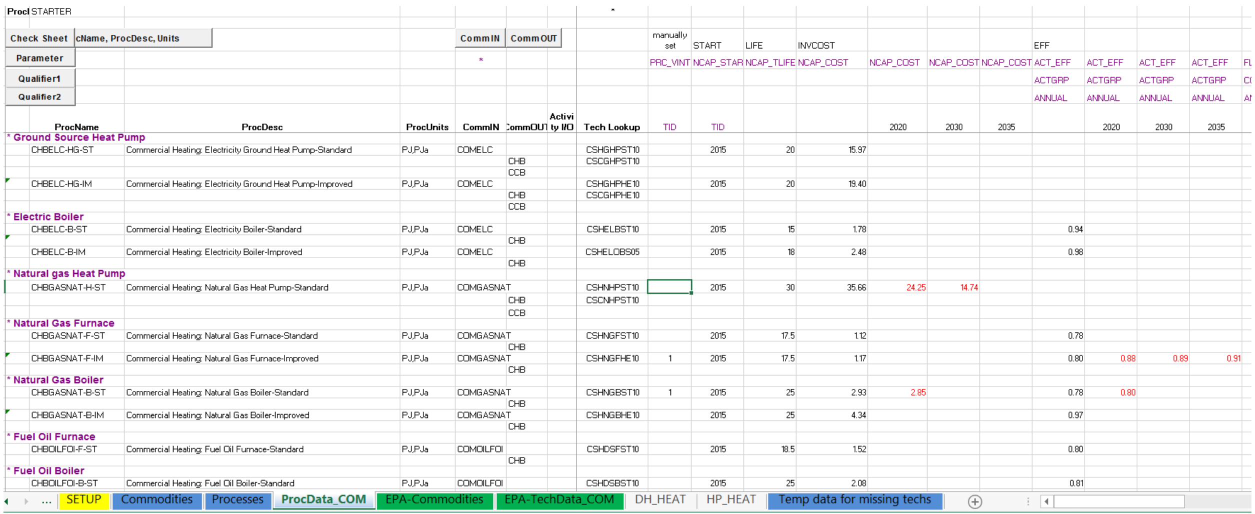
**Lighting Technology Quality & Type**

| | | |
|---|---|---|
| * Quality | | |
| | AD | Advanced |
| | BE | Best |
| | IM | Improved |
| | ST | Standard |
| | X1 | Existing1 |
| * Lighting Type | | |
| | -C- | CFL- |
| | -F- | Fluorescent- |
| | -H- | Halogen- |
| | -I- | Incandescent- |
| | -L- | LED- |
| | -D- | High Intensity Discharge- |
| | -R- | Reflector- |

As discussed above, the BY template includes an EB sheet tied to the EB workbook, both the BY and NT templates have SETUP and Commodity/Process declaration sheets. The NT SETUP tab is linked directly to the corresponding BY sheet for the commodity and device names to help ensure consistency. The final sheet (ProcData_XPRCs ) defines the sector fuel and emissions tracking processes (XCOM<fuel>) that link the supply commodities to the Commercial sector, and is only found in the BY sheet. If new commodities not found in the original first year energy balance are needed for future years, as discussed in Section 6, the 0 on row-5 of the BY-COM EB sheet for said fuel should be deleted, activating the fuel and associated XCOM<fuel> process.

One difference from MARKAL is that heat pumps are represented as a single device servicing both heating and cooling demands, with differing capacity factors and efficiencies. A snapshot of the Commercial load sheet, depicting the Lighting technology data, is shown in Figure 22. In the case of this example, using lighting, note that the units are in billion lumens (lbn-lum).

## Figure 22: New Technology Commercial Loadsheet




| ProcName | ProcDesc | ProcUnits | CommIN | CommOUT | Activity I/O | Tech Lookup | manually set PRC_VINT TID | START NCAP_STAR TID | LIFE NCAP_TLIFE | INVCOST NCAP_COST | NCAP_COST 2020 | NCAP_COST 2030 | NCAP_COST 2035 | EFF ACT_EFF ACTGRP ANNUAL | ACT_EFF ACTGRP ANNUAL 2020 | ACT_EFF ACTGRP ANNUAL 2030 | ACT_EFF ACTGRP ANNUAL 2035 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| * Ground Source Heat Pump | | | | | | | | | | | | | | | | | |
| CHBELC-HG-ST | Commercial Heating: Electricity Ground Heat Pump-Standard | PJ,PJa | COMELC | | | CSHGHPST10 | | 2015 | 20 | 15.97 | | | | | | | |
| | | | | CHB | | CSCGHPST10 | | | | | | | | | | | |
| | | | | CCB | | | | | | | | | | | | | |
| CHBELC-HG-IM | Commercial Heating: Electricity Ground Heat Pump-Improved | PJ,PJa | COMELC | | | CSHGHPHE10 | | 2015 | 20 | 19.40 | | | | | | | |
| | | | | CHB | | CSCGHPHE10 | | | | | | | | | | | |
| | | | | CCB | | | | | | | | | | | | | |
| * Electric Boiler | | | | | | | | | | | | | | | | | |
| CHBELC-B-ST | Commercial Heating: Electricity Boiler-Standard | PJ,PJa | COMELC | | | CSHELBST10 | | 2015 | 15 | 1.78 | | | | 0.94 | | | |
| | | | | CHB | | | | | | | | | | | | | |
| CHBELC-B-IM | Commercial Heating: Electricity Boiler-Improved | PJ,PJa | COMELC | | | CSHELOBS05 | | 2015 | 18 | 2.48 | | | | 0.98 | | | |
| | | | | CHB | | | | | | | | | | | | | |
| * Natural gas Heat Pump | | | | | | | | | | | | | | | | | |
| CHBGASNAT-H-ST | Commercial Heating: Natural Gas Heat Pump-Standard | PJ,PJa | COMGASNAT | | | CSHNHPST10 | | 2015 | 30 | 35.66 | 24.25 | 14.74 | | | | | |
| | | | | CHB | | CSCNHPST10 | | | | | | | | | | | |
| | | | | CCB | | | | | | | | | | | | | |
| * Natural Gas Furnace | | | | | | | | | | | | | | | | | |
| CHBGASNAT-F-ST | Commercial Heating: Natural Gas Furnace-Standard | PJ,PJa | COMGASNAT | | | CSHNGFST10 | | 2015 | 17.5 | 1.12 | | | | 0.78 | | | |
| | | | | CHB | | | | | | | | | | | | | |
| CHBGASNAT-F-IM | Commercial Heating: Natural Gas Furnace-Improved | PJ,PJa | COMGASNAT | | | CSHNGFHE10 | 1 | 2015 | 17.5 | 1.17 | | | | 0.80 | 0.88 | 0.89 | 0.91 |
| | | | | CHB | | | | | | | | | | | | | |
| * Natural Gas Boiler | | | | | | | | | | | | | | | | | |
| CHBGASNAT-B-ST | Commercial Heating: Natural Gas Boiler-Standard | PJ,PJa | COMGASNAT | | | CSHNGBST10 | 1 | 2015 | 25 | 2.93 | 2.85 | | | 0.78 | 0.80 | | |
| | | | | CHB | | | | | | | | | | | | | |
| CHBGASNAT-B-IM | Commercial Heating: Natural Gas Boiler-Improved | PJ,PJa | COMGASNAT | | | CSHNGBHE10 | | 2015 | 25 | 4.34 | | | | 0.97 | | | |
| | | | | CHB | | | | | | | | | | | | | |
| * Fuel Oil Furnace | | | | | | | | | | | | | | | | | |
| CHBOILFOI-F-ST | Commercial Heating: Fuel Oil Furnace-Standard | PJ,PJa | COMOILFOI | | | CSHDSFST10 | | 2015 | 18.5 | 1.52 | | | | 0.80 | | | |
| | | | | CHB | | | | | | | | | | | | | |
| * Fuel Oil Boiler | | | | | | | | | | | | | | | | | |
| CHBOILFOI-B-ST | Commercial Heating: Fuel Oil Boiler-Standard | PJ,PJa | COMOILFOI | | | CSHDSBST10 | | 2015 | 25 | 2.08 | | | | 0.81 | | | |

Any Commercial component may be eliminated by entering "*" in Col-A on the SETUP sheet. If there is a need to add a new device type, do so by copying a similar type of devices' name on SETUP then Process data blocks on the appropriate ProcData_* sheets. Most of the names are carefully built from $references to their components, so after copying only minor adjustments need to be done to say change a fuel or technology instance. However, if adding a new technology there will be no corresponding data on the source data sheets, so the appropriate numbers will need to be provided. Also, be sure when adding an existing device not yet in the database that the device also gets added to the Calibration sheet appropriately (by copy/inserting a similar device in the same group).

> **Warning**: be sure to adhere to the basic naming convention of the components (that is use the same approach and number of characters as for some other entry) or the ANSWER named TechFilters and VBE Sets may no long operate properly!

### *5.4.2.1 Calibration of the Initial Year*

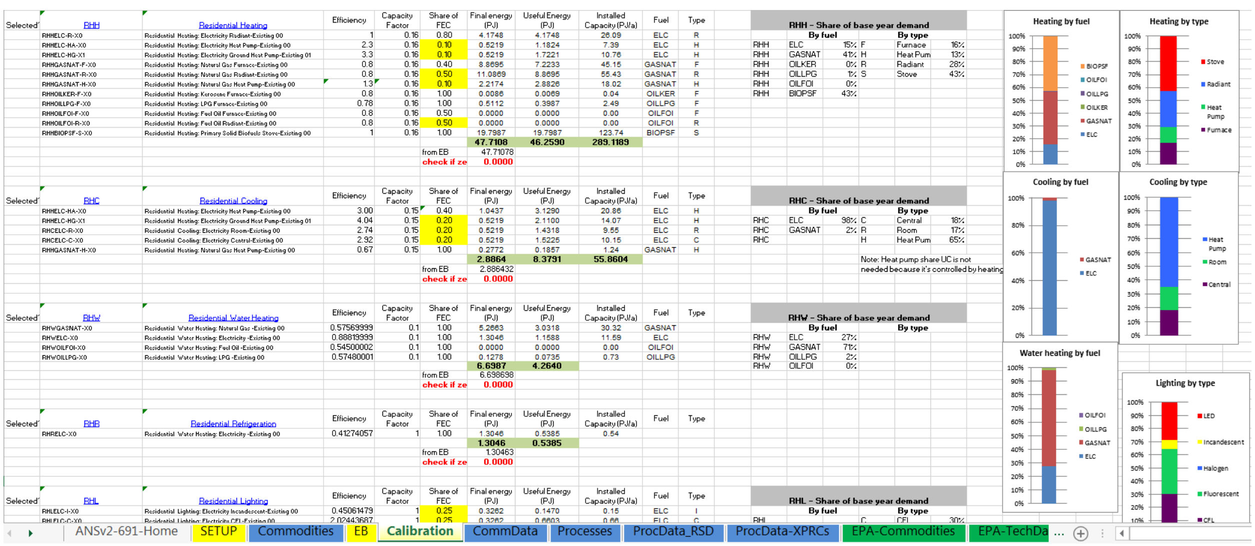
The Residential and Commerical sectors are very similar in terms of preparing and performing the calibration as for the most part they tend to have the same kinds energy services and devices types that meet them. Below in Figure 23 and Figure 24 the EB and Calibration sheets are shown, where the user input of the splits for the end-use services is done on the former and for the associated devices on the latter. When entering the device splits when there is more than one competing device consuming a fuel, shares are requested for all but one of them, with the remaining share calculated to ensure the service/fuel total is respected.

On the Calibration sheet, to the right of the calibration table, summary tables and graphs show the percentage of useful energy (end use service demand) provided by each fuel and/or device type. As these are end use service demand shares, they can be thought of in the Commercial/Residential sector as loosely the share of building type using each fuel/device type. As such, they can serve as feedback on the reasonableness of the fuel and device final energy shares the user has assigned. (For example, they may be compared with survey data on household energy/device use.) However, any changes needed in these service demand shares should be accomplished by adjusting the split of sector fuel consumption to the service demands on the EB or the final energy device shares in the Calibration table until the desired service demand shares are seen in the graphs/summary tables. These percentages also drive the Reference scenario guidance user constraints described in Section 10.

**Figure 23: EB Sheet for Residential and Commercial**

| | | COAANT | OILLPG | OILGSL | OILKER | OILDSL | OILFOI | GASNAT | BIOPSF | RNWGEO | RNWSOL | ELC | LTH | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PJ | Sector Name | Anthracite | LPG | Gasoline | Kerosene | Diesel | Fuel Oil | Natural Gas | Biomass | Geothermal | Solar | Electricity | Heat | Total of All Energy Sources |
| Residential | RSD | 0 | 0.639 | 0 | 0.0086 | 0 | 0 | 27.7172 | 19.7987 | 0.208 | 0.0233 | 13.0463 | 0 | 61.4921 |
| | | | | | | | | | | | | | | |
| Split each by end-use | | | | | | | | | | | | | | |
| RHH | Residential Heating | | 80% | | 100% | | | 80% | 100% | | | 40% | | |
| RHC | Residential Cooling | | | | | | | 1% | | | | 20% | | |
| RHW | Residential Water Heating | | 20% | | | | | 19% | | | | 10% | | |
| RHR | Residential Refrigeration | | | | | | | | | | | 10% | | |
| RHK | Residential Freezing | | | | | | | | | | | | | |
| RHL | Residential Lighting | | | | | | | | | | | 10% | | |
| RHO | Residential Other Appliances | | | | | | | | | | | 10% | | |
| | Residential Other Appliances - NGA | | | | | | | | | | | | | |
| | Residential Other Appliances - LPG | | | | | | | | | | | | | |
| | **Check 100%** | **0%** | **100%** | **0%** | **100%** | **0%** | **0%** | **100%** | **100%** | **0%** | **0%** | **100%** | **0%** | |
| | | | | | | | | | | | | | | |
| FEC by end-use | | | | | | | | | | | | | | |
| RHH | Residential Heating | 0 | 0.5112 | 0 | 0.0086 | 0 | 0 | 22.17376 | 19.7987 | 0 | 0 | 5.21852 | 0 | **47.71078** |
| RHC | Residential Cooling | 0 | 0 | 0 | 0 | 0 | 0 | 0.277172 | 0 | 0 | 0 | 2.60926 | 0 | **2.886432** |
| RHW | Residential Water Heating | 0 | 0.1278 | 0 | 0 | 0 | 0 | 5.266268 | 0 | 0 | 0 | 1.30463 | 0 | **6.698698** |
| RHR | Residential Refrigeration | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.30463 | 0 | **1.30463** |
| RHK | Residential Freezing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| RHL | Residential Lighting | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.30463 | 0 | **1.30463** |
| RHO | Residential Other Appliances | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.30463 | 0 | **1.30463** |
| | Residential Other Appliances - NGA | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| | Residential Other Appliances - LPG | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| | **Total** | **0** | **0.639** | **0** | **0.0086** | **0** | **0** | **27.7172** | **19.7987** | **0** | **0** | **13.0463** | **0** | **61.2098** |
| | Check diff from FEC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.208 | 0.0233 | 0 | 0 | 0.2823 |

**Figure 24: Calibration Sheet for Residential and Commercial**



As discussed in Section 6, the work on the Calibration sheets in each BY workbook is the starting point for the calibration process. The cycle involves running the model (for just the first period if desired) and using the VBE calibration check workbook to see how well the model is aligning with the energy balance, returning to the BY Calibration sheets to devices shares assumptions as needed.

### 5.4.3 Industry and Oil Refinery

#### *5.4.3.1 Overview*

Because the Industrial sector is comprised of sub-sectors that are much more unique than the common residential and commercial end-use services, a generalized industry sector cannot be pre-assembled in the Starter model. Instead, what is provided is a process for assembling a country-specific industry sector from a combination of EPA and local sources of data.

The approach to modeling the Industrial sector is based on the EPA approach where each industry sub-sector has a single demand, which corresponds to that sub-sector's activity (output), and a single demand device, which requires specific end-use services, such as process heat, machine drive, etc., to produce a unit of industrial output.

The Starter model energy balance structure is based upon the IEA energy balance categories for Non-OECD countries, which as shown in Table 7 has 13 entries. However, the EPA database contains end-use service shares and technology characterizations for 19 industry sub-sectors, and the overlap between these is illustrated in Table 7 under the EPA header. For example, where EPA has Primary and Secondary steel, IEA has only Iron and Steel. Therefore, the process for building an industry sector in the Starter model begins with identification and mapping of the country's industry sub-sectors, as defined in their national energy balance, to the EPA sub-sectors. Local industry sub-sector experts will need to be consulted to ensure accurate characterization of their particular sub-sector.

The following examples are provided to help illustrate mapping decisions.

1. The energy balance has one entry for Iron and steel: If a primary steel industry exists, look for data on the activity split between primary and secondary (e.g., recycled steel for rebar) production. If no primary steel industry exists, use the Secondary steel end-use service shares and technology characterizations.
2. A similar approach can be taken with Non-ferrous metals. If primary aluminum production exists, look for data on the activity split between primary and secondary production and other metals (e.g., copper, nickel, tin) if they exist. Use the end-use service shares and technology characterizations for each of the sub-sector processes that have activity.
3. Similarly for Non-metallic minerals, if a Glass industry exists, look for activity data on glass and cement (which will exist in most countries) to determine their share of total Non-metallic minerals activity. Use the end-use service shares and technology characterizations for each of the sub-sector processes that have activity.
4. The Paper, pulp and print sub-sector is not as simple as the other sub-sectors, because pulp and paper facilities are often integrated. If activity shares exist, then these can be used, but if not an integrated set of end-use service shares and technology characterizations have been synthesized from the EPA data.

**Table 7: Mapping of Starter and EPA Industry Subsectors**

| STARTER | EPA | | | | |
|---|---|---|---|---|---|
| Iron and steel | Primary Steel | Secondary Steel | | | |

| | | | | | |
|---|---|---|---|---|---|
| Chemicals and petrochemicals | Organic Chemicals | Inorganic Chemicals | Plastics, fibers, resins | Agricultural Chemicals | Other Chemicals |
| Non-ferrous metals | Primary Aluminum | Secondary Aluminum | Other metals | | |
| Non-metallic minerals | Cement | Glass | Other non-metals | | |
| Transport equipment | Other | | | | |
| Machinery | Other | | | | |
| Mining and quarrying | Other | | | | |
| Food and tobacco | Food | | | | |
| Paper, pulp and print | Pulp | Paper | Paperboard | Other pulp & paper | |
| Wood and wood products | Other | | | | |
| Construction | Other | | | | |
| Textile and leather | Other | | | | |
| Non-specified | Other | | | | |

The Industrial sector is handled in a similar manner to the rest of the EPA US9r referenced templates, in that the SETUP sheet controls what is and is not included for the sector. But because the sector is more complex and requires more local information than the other demand sectors, this Guideline document only provides an example of the set-up of one sector (Iron and Steel) with all other industry energy use incorporated into an Other Industry sector. As is the case with the other TIMES-Starter sector workbooks the ProcData_<subsector> sheets link directly to their EPA-TechData_<subsector> counterpart via VLOOKUPs, converting costs as specified on the SETUP sheet.

The Starter IND templates include placeholders for the following Industry subsectors, using the naming conventions shown in Table 8. Following this example for the Iron and Steel subsector, other sub-sectors can be activated by removing the * from Col-A of the Set-up tab and by adding the existing technology and new technology options for that subsector into new tabs in the BY and NT templates, as described more below.

**Table 8: Industry Subsector Options**

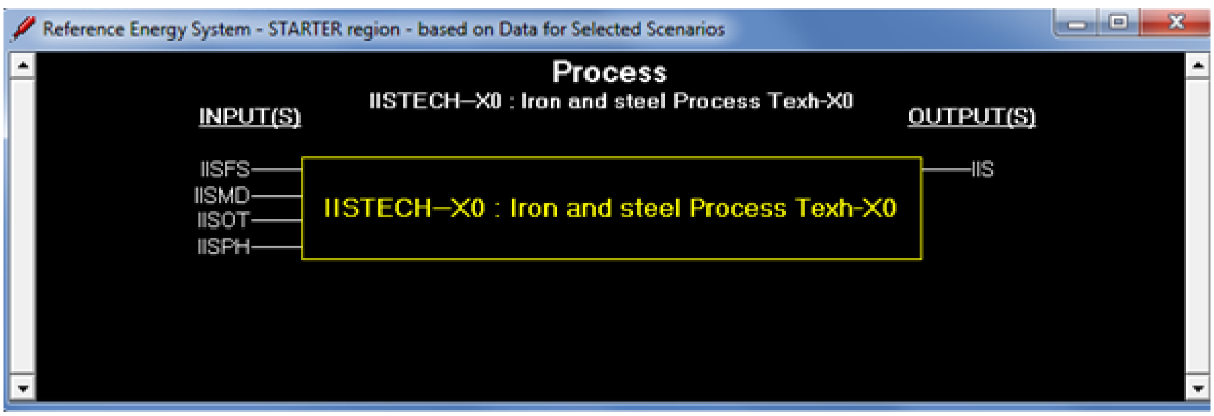
| ID | Description |
|---|---|
| IIS | Iron and steel |
| ICH | Chemical and petrochemical |
| INF | Non-ferrous metals |
| INM | Non-metallic minerals |
| ITE | Transport equipment |
| IMC | Machinery |
| IMM | Mining and quarrying |
| IFB | Food and tobacco |
| IPP | Paper, pulp and print |
| IWP | Wood and wood products |

| | |
|---|---|
| ICN | Construction |
| ITX | Textile and leather |
| IOT | Other |
| IFE | Industry Other (temp) - All |

### 5.4.3.2 Configuring Industry Sub-sectors – Iron & Steel Example

This example of the Iron and Steel (IIS) industry is fully established in the TIMES-Starter, and the associated BY, NT and UC templates are discussed here.  For the IIS sub-sector, there is a single demand, which corresponds to industry activity, and a single demand device (IISTECH-X0) which draws on each of the end-use services (PH-process heat, MD-motor drive, FS-feedstocks and OT-Facilities/Other) needed for that sector to deliver a unit of industrial output, as shown in Figure 25.

**Figure 25: Industry – Steel End-use Services**




The energy carriers used by the IIS subsector can be identified from the energy balance, but local information is then needed to determine what portion of these energy carriers are used for process heat facilities, motor drive and feedstocks.  Subsector data should be used where available and expert judgment used in its absence.  As shown below for IIS in the excerpt from the Setup tab of the BY-IND template, an existing technology has been characterized for each non-zero energy carrier/end-use combination, and the corresponding EPA technology identified in the EPA Tech column.

| *** Iron and Steel** | | |
|---|---|---|
| *** Techs by fuel  and end-use application** | | **EPA Tech** |
| IISCOAOBCPH-X0 | Industry: Iron and steel - Bituminous (Brown Coal) -Process heat- Existing 00 | IMSEPRHCOA |
| IISCOALIGPH-X0 | Industry: Iron and steel - Lignite -Process heat- Existing 00 | IMTEPRHCOA |
| IISCOAORGFS-X0 | Industry: Iron and steel - Other coal product -Feedstock- Existing 00 | IMSEFEDCOK |
| IISOILGSLOT-X0 | Industry: Iron and steel - Gasoline -Facilities/Other- Existing 00 | IMSEFACDST |
| IISOILKEROT-X0 | Industry: Iron and steel - Kerosene -Facilities/Other- Existing 00 | IMSEFACDST |
| IISOILDSLOT-X0 | Industry: Iron and steel - Diesel -Facilities/Other- Existing 00 | IMSEFACDST |
| IISOILFOIOT-X0 | Industry: Iron and steel - Fuel Oil -Facilities/Other- Existing 00 | IMTEOHTRFL |
| IISGASNATPH-X0 | Industry: Iron and steel - Natural Gas -Process heat- Existing 00 | IMTEPRHNGA |
| IISGASNATOT-X0 | Industry: Iron and steel - Natural Gas -Facilities/Other- Existing 00 | IMTEFACNGA |
| IISBIOPSFOT-X0 | Industry: Iron and steel - Primary Solid Biofuels -Facilities/Other- Existing 00 | IMTEOHTBIO |

| | | |
|---|---|---|
| IISELCPH-X0 | Industry: Iron and steel - Electricity -Process heat- Existing 00 | IMTEPRHELC |
| IISELCMD-X0 | Industry: Iron and steel - Electricity -Machine Drive- Existing 00 | IMTEMDRELC |
| IISELCOT-X0 | Industry: Iron and steel - Electricity -Facilities/Other- Existing 00 | IMTEFACELC |

Similarly, in the NT-IND template, both Standard and Improved new technology options are generated for the above Existing technology options along with any new energy carrier/end-use application combinations not currently existing but envisioned for the future (where the user needs to “ “ out the 0 in the BY-IND EB sheet to activate a commodity not in the current energy balance that is to be available in the future).

The next step in development of the IIS subsector is calibration of the Existing technologies by factoring in the efficiency of the end-use devices. Typical boiler efficiencies are used for the process heat applications, but for the other end-uses (feedstocks, facilities, and motor drive) the EPA database uses efficiency =1, so that only final energy is tracked for these end-use applications. Where end-use efficiency measures are desired, these can be modelled as conservation technologies that reduce final energy use when purchased and deployed.

The Calibration sheet determines the useful energy demand and capacity of existing technologies, and determines the proportions of each IIS end-use service needed to produce a unit of output. These values are used in the template to determine the fixed activity shares as shown below.

| | Scenario | Parameter | | Region | Process | CommGroup | TimeSlice | I/E | 2013 |
|---|---|---|---|---|---|---|---|---|---|
| M | BY-IND | ACT_FLO | ? | STARTER | IISTECH-X0 | IISFS | ANNUAL | 0 | 0.0682 |
| M | BY-IND | ACT_FLO | ? | STARTER | IISTECH-X0 | IISMD | ANNUAL | 0 | 0.1321 |
| M | BY-IND | ACT_FLO | ? | STARTER | IISTECH-X0 | IISOT | ANNUAL | 0 | 0.1002 |
| M | BY-IND | ACT_FLO | ? | STARTER | IISTECH-X0 | IISPH | ANNUAL | 0 | 0.6995 |

For each of these end-use services there are a number of technology/energy carrier options, which are shown in Figure 26 for IIS Process heat applications. Here we can see that the IIS process heat demand can be met by existing, standard new and improved new technologies consuming coal, natural gas, electricity and process heat from cogeneration plants. A longer list of technology options is available to meet the facility/other services demand, as shown in Figure 27, as well as for feedstocks and motor drive demands.

Figure 26: Iron & Steel – Technologies for Process Heat Production

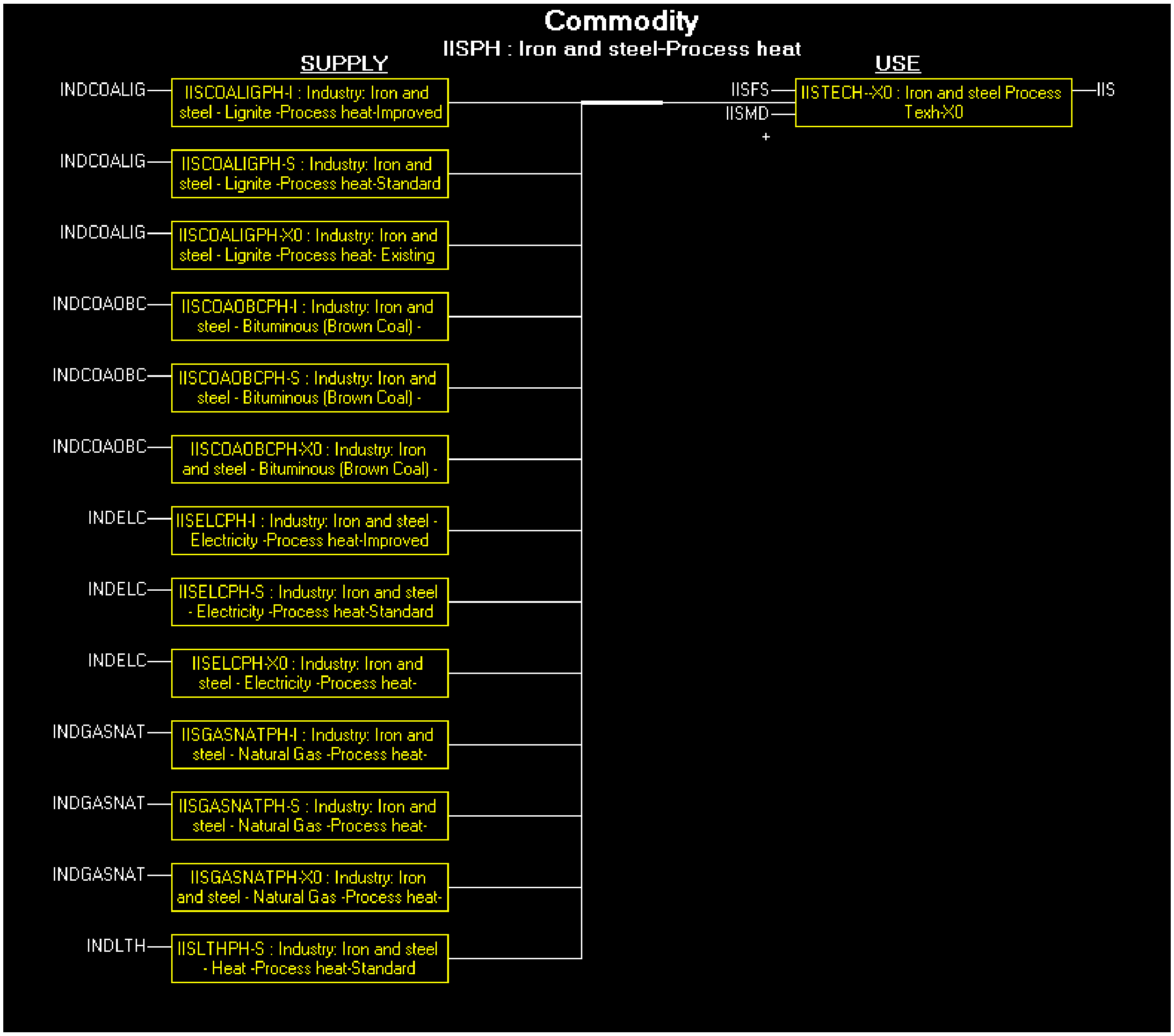
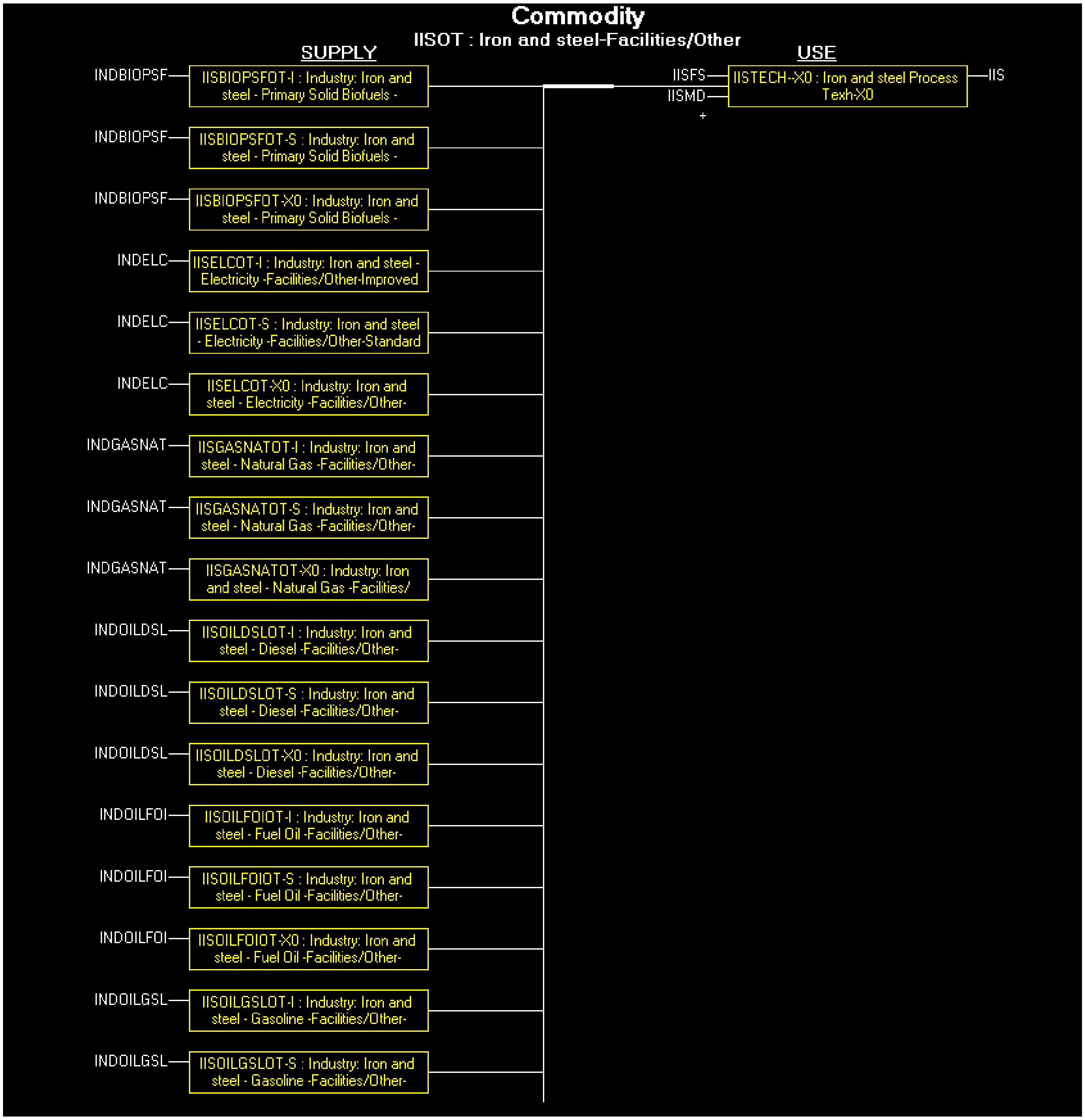


Figure 27: Iron & Steel – Technologies for Facilities/Other End-uses




The final step in establishing the IIS industry subsector is the enumeration of user constraints (UCs) for the sub-sector fuel shares, which will provide guidelines for the allowed changes in the share of a specific energy carrier. The starting shares (2015) are linked to the BY shares developed in the BY template on the calibration sheet, as seen in Figure 28. The user must then decide if each energy carriers/end-use application needs a bound. UP bounds will limit growth, while LO bounds will limit the decline of a technology.

### Figure 28: Iron & Steel – UCs to Guide Future Fuel Shares

TS&TID DATA STARTER

Check Sheet | Populate DataYears

| | LO | UP |
|---|---|---|
| Fuel Relaxation Factor | 10% | 10% |
| Tech Relaxation Factor | 10% | 10% |

| | AD | BE | IM |
|---|---|---|---|
| Max 2050 share | 10% | 20% | 30% |

| Parameter | Constraint Name | EQ Side | Process or TechFilter | Commodity | Timeslice | Type | I/E Opt or Value | 2013 | 2015 | 2020 | 2030 | 2040 | 2050 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | Arg1 | Arg2 | Arg3 | Arg4 | Arg5 | | Arg6 | I/E Opt | | | | | | |
| * Iron & Steel - Facility | | | | | | | | | | | | | | |
| UCRULE_MARK | IIS-OT-F-GSL-LO | - | IIS-OT-F-GSL | IISOT | - | LO | 5 | | 0.000 | | | | 0.000 | |
| UCRULE_MARK | IIS-OT-F-KER-LO | - | IIS-OT-F-KER | IISOT | - | LO | 5 | | 0.000 | | | | 0.000 | |
| UCRULE_MARK | IIS-OT-F-DSL-LO | - | IIS-OT-F-DSL | IISOT | - | LO | 5 | | 0.000 | | | | 0.000 | |
| UCRULE_MARK | IIS-OT-F-FOI-LO | - | IIS-OT-F-FOI | IISOT | - | LO | 5 | | 0.013 | | | | 0.013 | Maintained at constant share |
| UCRULE_MARK | IIS-OT-F-GAS-UP | - | IIS-OT-F-GAS | IISOT | - | UP | 5 | | 0.108 | | | | 0.208 | |
| UCRULE_MARK | IIS-OT-F-PSF-LO | - | IIS-OT-F-PSF | IISOT | - | LO | 5 | | 0.000 | | | | 0.000 | |
| UCRULE_MARK | IIS-OT-F-ELC-UP | - | IIS-OT-F-ELC | IISOT | - | UP | 5 | | 0.879 | | | | 0.879 | Maintained at constant share |
| * Iron & Steel - Process Heat | | | | | | | | | | | | | | |
| UCRULE_MARK | IIS-PH-F-OBC-LO | - | IIS-PH-F-OBC | IISPH | - | LO | 5 | | 0.005 | | | | 0.000 | |
| UCRULE_MARK | IIS-PH-F-LIG-LO | - | IIS-PH-F-LIG | IISPH | - | LO | 5 | | 0.003 | | | | 0.000 | |
| UCRULE_MARK | IIS-PH-F-GAS-UP | - | IIS-PH-F-GAS | IISPH | - | UP | 5 | | 0.043 | | | | 0.143 | |
| UCRULE_MARK | IIS-PH-F-ELC-UP | - | IIS-PH-F-ELC | IISPH | - | UP | 5 | | 0.950 | | | | 0.950 | Maintained at constant share |

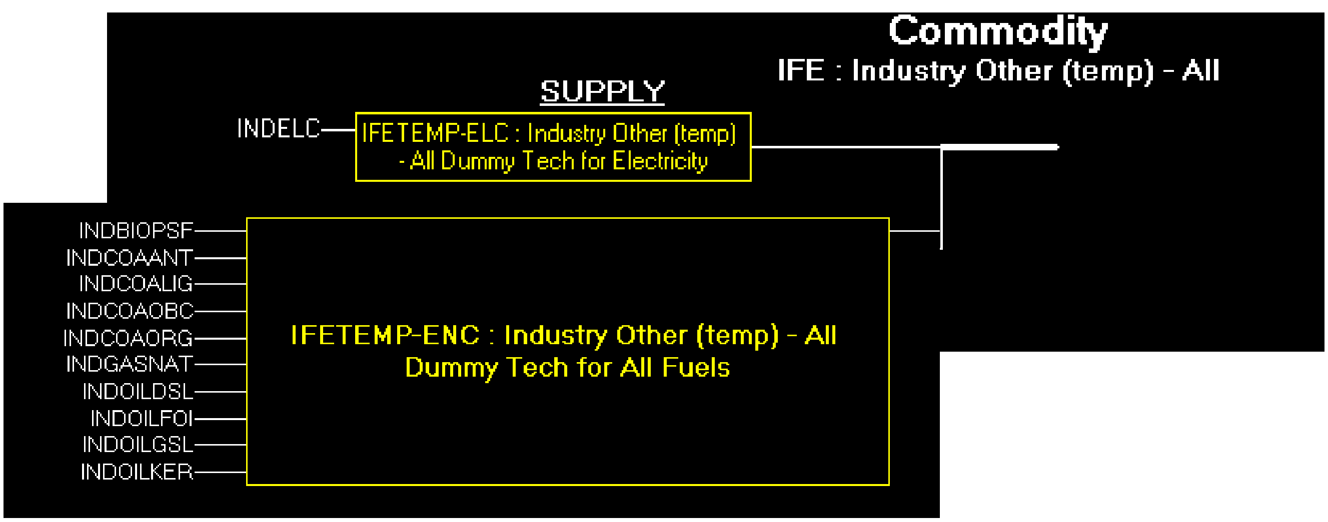
Pat DeLaquil:
Replace calculated value with local data where available.

ANSv1-691-Home | ITEMS | TS&TID DATA-UC

### *5.4.3.3 Other Industry Subsectors*

For the TIMES-Starter, the industry energy use from remaining subsectors is aggregated into a temporary all other industry demand (IFE). For this "other" category, only final energy shares for electricity and fuels are modeled. Once the local industry subsectors are removed from other and described by their existing and new technologies, this approach will be appropriate for the remaining other industry demand. For this example of the other industry sub-sector, the Industry Other (temp) demand (IFE) is met by a combination of fuels and electricity, which have market shares of 67.2% and 32.8% respectively. Within the fuels group, there are flow shares to apportion the fuels comprising the 67.2% of total energy demand, as shown in Table 9. These shares are set in the BY-IND template on the ProcData_IND(temp) sheet and in the Starter templates, kept constant over the planning horizon. However, the composition of fuels and electricity may be adjusted over time if the composition of the Other subsector is expected to change over time.

### Figure 29: Industry – End-use Service Alignment between US9r and Country



### Table 9: Starter Industry Subsector Options

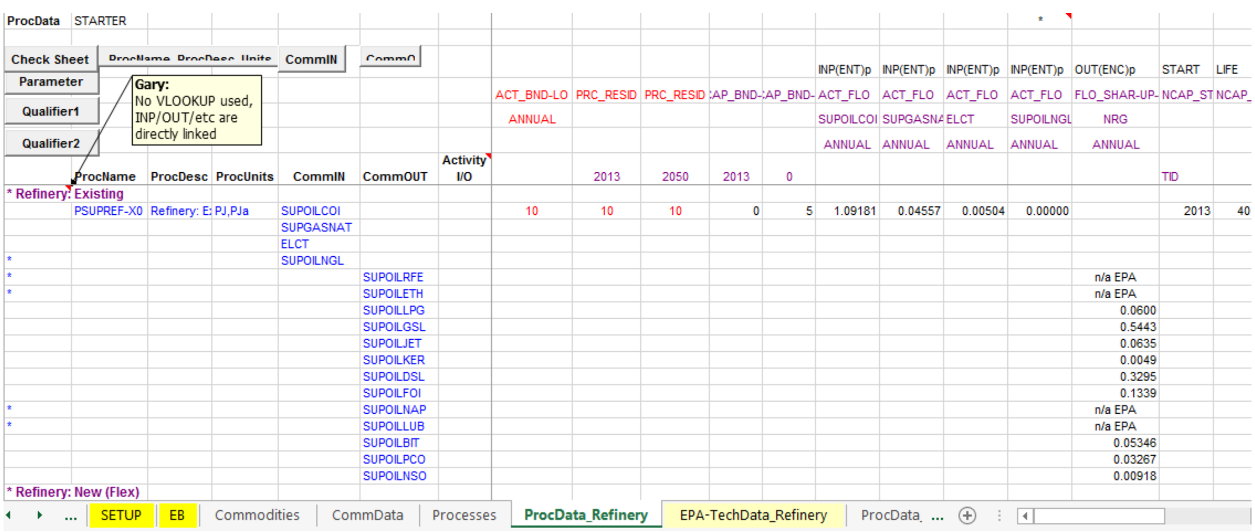
| Energy Carrier | Flow Share | Market Share |
|---|---|---|
| INDCOAANT | 1.20% | |
| INDCOAOBC | 9.48% | |
| INDCOALIG | 37.74% | |
| INDCOAORG | 21.05% | |
| INDOILKER | 0.05% | |
| INDOILDSL | 13.62% | |
| INDOILFOI | 0.25% | |
| INDGASNAT | 14.53% | |
| IND<ent> | | 67.19% |
| INDELC | | 32.81% |

## 5.4.4 Simple Flexible Oil Refinery

The AT2-Starter_RefineryO template is setup with an existing and a new limit refineries established based upon the US9r allocation for PADD2 in terms of costs and output mix maximum shares for each product in the slate (corresponding to the OUT(ENC)p/FLO_SHAR(up)), anticipating that the user will need to adjust these for their historic/expected situation in there. The refinery is output normalized, where 1 PJ of the output slate requires 1.09181PJ crude oil, 0.04557PJ natural gas, and 0.00504PJ electricity. For the existing refinery the current installed capacity (PRC_RESID) should be updated and perhaps the first period total output, as shown in red in Figure 30.

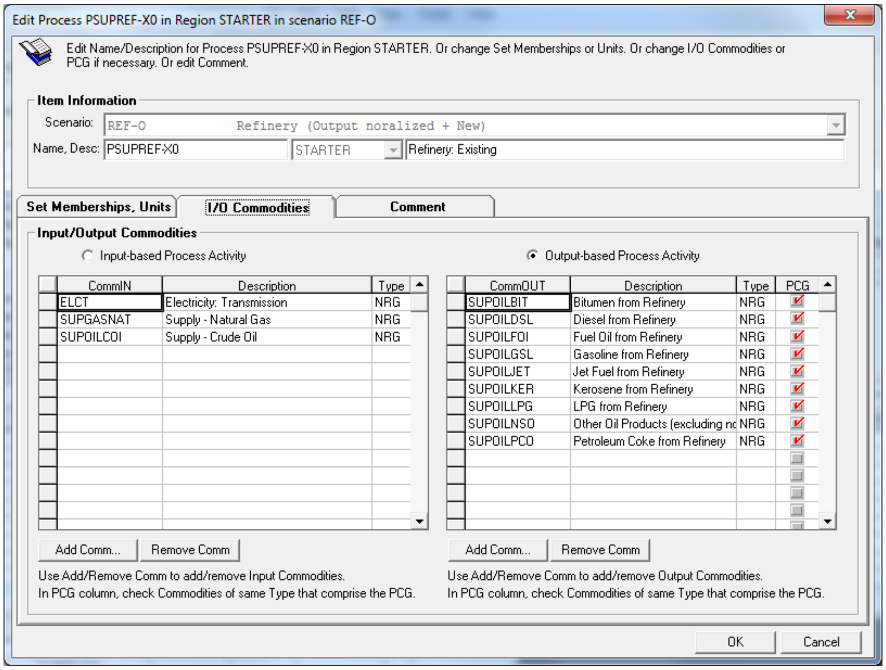
The Setup and Commodities sheet of the Refinery template link to the supply (SUP) template to get the names, descriptions, units and set membership of the commodities involved in the refinery operation.

### Figure 30: Refinery Template




In ANSWER the Refinery setup with respect to the PCG (output) and SPG (input) can be seen nicely on the Edit I/O Commodities form, as seen in Figure 31.

## Figure 31: Refinery PCG




##### 5.4.4.1 *Calibration of the Initial Year*

To check the calibration of the refinery, that is the production slate or product mix in the first period, use the VEDA-BE Refinery Product Mix table, adjusting the FLO_SHAR in the 1$^{st}$ period as necessary – perhaps moving to FLO_SHAR(FX) for said period, then allowing more flexibility in the later years.

#### 5.4.5 Residential

The structure of the Residential sector templates is very similar to those of the Commercial sector, where the list of energy service demands are defined for a set of end-use applications, as can be seen in Figure 32, with each of these applications serviced by multiple (sometimes many) devices. The energy service, building type, fuel consumed and device type are combined to form the name (and description) of each of the options. In the case of heating/cooling, the Building type is appended to the demand root so that if additional building types are added they are properly distinguished in all the device names. Figure 33 demonstrates this by listing some of the devices for Residential space heating as found in US9r. The layout of devices is similar for the other end-use applications. These various heating/cooling options need to be apportioned by the user according to the general situation in the area of study, otherwise the single most cost-effective option will dominate the service demand. The multiple vintages of a technology in the EPA MARKAL model are replaced by a single technology option by using the vintage feature in TIMES, and heat pumps are represented by a single technology in TIMES.

**Figure 32: Residential End-Uses & Heating Technology Types**

| Building Type & End-Use Applications | Heating Technology Types |
|---|---|

| | | |
|---|---|---|
| * **Building Types** | | |
| | H | |
| * **Energy Services** | | |
| | RHH | Residential Heating |
| | RHC | Residential Cooling |
| | RHW | Residential Water Heating |
| | RHR | Residential Refrigeration |
| * | RHK | Residential Freezing |
| | RHL | Residential Lighting |
| | RHO | Residential Other Appliances |

| | | |
|---|---|---|
| * **Heating Device Type** | | |
| | -F- | Furnace- |
| | -H- | Heat Pump- |
| | -R- | Radiant- |
| | -S- | Stove- |

**Figure 33: Residential Heating Technologies**

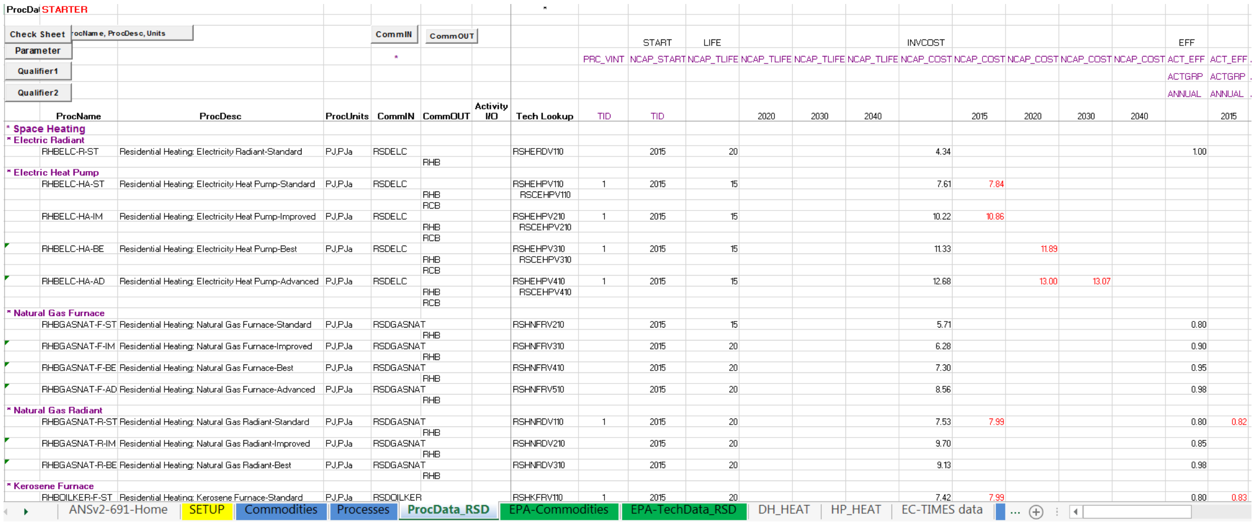
| | | |
|---|---|---|
| * **Space Heating** | | |
| * **Electric Radiant** | | |
| | RHHELC-R-ST | Residential Heating: Electricity Radiant-Standard |
| * **Electric Heat Pump** | | |
| | RHHELC-HA-ST | Residential Heating: Electricity Heat Pump-Standard |
| | RHHELC-HA-IM | Residential Heating: Electricity Heat Pump-Improved |
| | RHHELC-HA-BE | Residential Heating: Electricity Heat Pump-Best |
| | RHHELC-HA-AD | Residential Heating: Electricity Heat Pump-Advanced |
| * **Natural Gas Furnace** | | |
| | RHHGASNAT-F-ST | Residential Heating: Natural Gas Furnace-Standard |
| | RHHGASNAT-F-IM | Residential Heating: Natural Gas Furnace-Improved |
| | RHHGASNAT-F-BE | Residential Heating: Natural Gas Furnace-Best |
| | RHHGASNAT-F-AD | Residential Heating: Natural Gas Furnace-Advanced |
| * **Natural Gas Radiant** | | |
| | RHHGASNAT-R-ST | Residential Heating: Natural Gas Radiant-Standard |
| | RHHGASNAT-R-IM | Residential Heating: Natural Gas Radiant-Improved |
| | RHHGASNAT-R-BE | Residential Heating: Natural Gas Radiant-Best |
| * **Kerosene Furnace** | | |
| | RHHOILKER-F-ST | Residential Heating: Kerosene Furnace-Standard |
| | RHHOILKER-F-IM | Residential Heating: Kerosene Furnace-Improved |
| | RHHOILKER-F-BE | Residential Heating: Kerosene Furnace-Best |

| | | |
|---|---|---|
| * **LPG Furnace** | | |
| | RHHOILLPG-F-ST | Residential Heating: LPG Furnace-Standard |
| | RHHOILLPG-F-IM | Residential Heating: LPG Furnace-Improved |
| | RHHOILLPG-F-BE | Residential Heating: LPG Furnace-Best |
| | RHHOILLPG-F-AD | Residential Heating: LPG Furnace-Advanced |
| * **Distillate Furnace** | | |
| | RHHOILFOI-F-ST | Residential Heating: Fuel Oil Furnace-Standard |
| | RHHOILFOI-F-IM | Residential Heating: Fuel Oil Furnace-Improved |
| | RHHOILFOI-F-BE | Residential Heating: Fuel Oil Furnace-Best |
| * **Distillate Radiant** | | |
| | RHHOILFOI-R-ST | Residential Heating: Fuel Oil Radiant-Standard |
| | RHHOILFOI-R-IM | Residential Heating: Fuel Oil Radiant-Improved |
| | RHHOILFOI-R-BE | Residential Heating: Fuel Oil Radiant-Best |
| * **Wood** | | |
| | RHHBIOPSF-S-ST | Residential Heating: Primary Solid Biofuels Stove-Standard |
| * **Ground Source Heat Pump** | | |
| | RHHELC-HG-ST | Residential Heating: Electricity Ground Source Heat Pump-Standard |
| | RHHELC-HG-IM | Residential Heating: Electricity Ground Source Heat Pump-Improved |
| * **Natural Gas Heat Pump** | | |
| * | RHHGASNAT-H-ST | Residential Heating: Natural Gas Heat Pump-Standard |
| * | RHHGASNAT-H-IM | Residential Heating: Natural Gas Heat Pump-Improved |

As noted above, the BY template includes an EB sheet tied to the EB workbook, both the BY and NT templates have SETUP and Commodity/Process declaration sheets. The NT SETUP tab is linked directly to the corresponding BY sheet for the commodity and device names to help ensure consistency. The final sheet (ProcData_XPRCs ) defines the sector fuel and emissions tracking processes (XRSD<fuel>) that link the supply commodities to the Residential sector, and is only found in the BY sheet. If new commodities not found in the original first year energy balance are needed for future years, as discussed in Section 6, the 0 on row-5 of the BY-RSD EB sheet for said fuel should be deleted, activating the fuel and associated XRSD<fuel> process.

The Residential sector is handled the same as the rest of the EPA US9r referenced templates, in that the SETUP sheet controls what is/is not included for the sector, and the ProcData_RSD sheet links directly to their EPA_RSD counterpart via VLOOKUP, converting costs as specified on the SETUP sheet. One difference from MARKAL is that heat pumps are represented as a single device servicing both heating and cooling demands, with differing capacity factors and efficiencies. A snapshot of the Residential load sheet is shown in Figure 34. All the residential service demands are in petajoules, with the exception of lighting in billion lumens (lbn-lum).

**Figure 34: Residential New Technology Loadsheet**



ProcDat STARTER

Check Sheet | ProcName, ProcDesc, Units | CommIN | CommOUT | Parameter | Qualifier1 | Qualifier2

| ProcName | ProcDesc | ProcUnits | CommIN | CommOUT | Activity I/O | Tech Lookup | PRC_VINT TID | START NCAP_START TID | LIFE NCAP_TLIFE | NCAP_TLIFE 2020 | NCAP_TLIFE 2030 | NCAP_TLIFE 2040 | INVCOST NCAP_COST | NCAP_COST 2015 | NCAP_COST 2020 | NCAP_COST 2030 | NCAP_COST 2040 | EFF ACT_EFF ACTGRP ANNUAL | ACT_EFF ACTGRP ANNUAL 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| * Space Heating | | | | | | | | | | | | | | | | | | | |
| * Electric Radiant | | | | | | | | | | | | | | | | | | | |
| RHBELC-R-ST | Residential Heating: Electricity Radiant-Standard | PJ,PJa | RSDELC | | | RSHERDV110 | | 2015 | 20 | | | | 4.34 | | | | | 1.00 | |
| | | | | RHB | | | | | | | | | | | | | | | |
| * Electric Heat Pump | | | | | | | | | | | | | | | | | | | |
| RHBELC-HA-ST | Residential Heating: Electricity Heat Pump-Standard | PJ,PJa | RSDELC | | | RSHEHPV110 | 1 | 2015 | 15 | | | | 7.61 | 7.84 | | | | | |
| | | | | RHB | | RSCEHPV110 | | | | | | | | | | | | | |
| | | | | RCB | | | | | | | | | | | | | | | |
| RHBELC-HA-IM | Residential Heating: Electricity Heat Pump-Improved | PJ,PJa | RSDELC | | | RSHEHPV210 | 1 | 2015 | 15 | | | | 10.22 | 10.86 | | | | | |
| | | | | RHB | | RSCEHPV210 | | | | | | | | | | | | | |
| | | | | RCB | | | | | | | | | | | | | | | |
| RHBELC-HA-BE | Residential Heating: Electricity Heat Pump-Best | PJ,PJa | RSDELC | | | RSHEHPV310 | 1 | 2015 | 15 | | | | 11.33 | | 11.89 | | | | |
| | | | | RHB | | RSCEHPV310 | | | | | | | | | | | | | |
| | | | | RCB | | | | | | | | | | | | | | | |
| RHBELC-HA-AD | Residential Heating: Electricity Heat Pump-Advanced | PJ,PJa | RSDELC | | | RSHEHPV410 | 1 | 2015 | 15 | | | | 12.68 | | 13.00 | 13.07 | | | |
| | | | | RHB | | RSCEHPV410 | | | | | | | | | | | | | |
| | | | | RCB | | | | | | | | | | | | | | | |
| * Natural Gas Furnace | | | | | | | | | | | | | | | | | | | |
| RHBGASNAT-F-ST | Residential Heating: Natural Gas Furnace-Standard | PJ,PJa | RSDGASNAT | | | RSHNFRV210 | | 2015 | 15 | | | | 5.71 | | | | | 0.80 | |
| | | | | RHB | | | | | | | | | | | | | | | |
| RHBGASNAT-F-IM | Residential Heating: Natural Gas Furnace-Improved | PJ,PJa | RSDGASNAT | | | RSHNFRV310 | | 2015 | 20 | | | | 6.28 | | | | | 0.90 | |
| | | | | RHB | | | | | | | | | | | | | | | |
| RHBGASNAT-F-BE | Residential Heating: Natural Gas Furnace-Best | PJ,PJa | RSDGASNAT | | | RSHNFRV410 | | 2015 | 20 | | | | 7.30 | | | | | 0.95 | |
| | | | | RHB | | | | | | | | | | | | | | | |
| RHBGASNAT-F-AD | Residential Heating: Natural Gas Furnace-Advanced | PJ,PJa | RSDGASNAT | | | RSHNFRV510 | | 2015 | 20 | | | | 8.56 | | | | | 0.98 | |
| | | | | RHB | | | | | | | | | | | | | | | |
| * Natural Gas Radiant | | | | | | | | | | | | | | | | | | | |
| RHBGASNAT-R-ST | Residential Heating: Natural Gas Radiant-Standard | PJ,PJa | RSDGASNAT | | | RSHNRDV110 | 1 | 2015 | 20 | | | | 7.53 | 7.99 | | | | 0.80 | 0.82 |
| | | | | RHB | | | | | | | | | | | | | | | |
| RHBGASNAT-R-IM | Residential Heating: Natural Gas Radiant-Improved | PJ,PJa | RSDGASNAT | | | RSHNRDV210 | | 2015 | 20 | | | | 9.70 | | | | | 0.85 | |
| | | | | RHB | | | | | | | | | | | | | | | |
| RHBGASNAT-R-BE | Residential Heating: Natural Gas Radiant-Best | PJ,PJa | RSDGASNAT | | | RSHNRDV310 | | 2015 | 20 | | | | 9.13 | | | | | 0.98 | |
| | | | | RHB | | | | | | | | | | | | | | | |
| * Kerosene Furnace | | | | | | | | | | | | | | | | | | | |
| RHBOILKER-F-ST | Residential Heating: Kerosene Furnace-Standard | PJ,PJa | RSDOILKER | | | RSHKFRV110 | 1 | 2015 | 20 | | | | 7.42 | 7.99 | | | | 0.80 | 0.83 |



Any Residential component may be eliminated by entering "*" in Col-A on the SETUP sheet. If there is a need to add a new device type, do so by copying a similar type of devices' name on SETUP then Process data blocks on the appropriate ProcData_* sheets. Most of the names are carefully built from $references to their components, so after copying only minor adjustments need to be done to say change a fuel or technology instance. However, if adding a new technology there will be no corresponding data on the source data sheets, so the appropriate numbers will need to be provided. Also, be sure when adding an existing device not yet in the database that the device also gets added to the Calibration sheet appropriately (by copy/inserting a similar device in the same group).

> **Warning**: be sure to adhere to the basic naming convention of the components (that is use the same approach and number of characters as for some other entry) or the ANSWER named TechFilters and VBE Sets may no long operate properly!

#### *5.4.5.1 Calibration of the Initial Year*

The Residential and Commerical sectors are very similar in terms of preparing and performing the calibration as for the most part they tend to have the same kinds energy services and devices types that meet them. See Section 5.4.2.1 for further explanation and examples.

As discussed in Section 6, the work on the Calibration sheets in each BY workbook is the starting point for the calibration process. The cycle involves running the model (for just the first period if desired) and using the VBE calibration check workbook to see how well the model is aligning with the energy balance, returning to the BY Calibration sheets to devices shares assumptions as needed.

### 5.4.6 Transportation

The EPA US9r database contains an extensive transportation sector database, which is provided in its entirety. Transportation demands are expressed in terms of Petajoules, vehicle miles traveled, passenger-miles and tonne-miles in US9r, converted internally in the templates to kilometers on the ProcData sheets as specified on the SETUP tab. The transportation demands, along with the types of vehicles modelled are shown in Figure 35. As discussed below, these various competing vehicles need to be apportioned by the user according to the general situation in the area of study, otherwise the single most cost-effective option will dominate the service demand.  The multiple vintages of a technology in the EPA MARKAL model are replaced by a single technology option by using the vintage feature in TIMES.

**Figure 35: Transportation Modes & Technology Classes**

**Transport Demands by Mode**

| | | |
|---|---|---|
| * Transport Services | | |
| * Light Duty | | |
| | TLD | Transport: Light Duty Vehicles |
| * Heavy Duty | | |
| | TAI | Transport: Air |
| | TBU | Transport: Bus |
| | TMD | Transport: Medium Duty Trucks |
| | THS | Transport: HDV Short Haul |
| | THL | Transport: HDV Long Haul |
| | TSH | Transport: Ship |
| | TRF | Transport: Rail - Freight |
| | TRP | Transport: Rail - Passanger |
| | TCT | Transport: Commercial Truck |
| * Off Road | | |
| | TOH | Transport: Off-road |

**Vehicle Classes**

| | |
|---|---|
| * LDV Vehicle Class | |
| CP | Compact |
| FS | Fullsize |
| LS | Large SUV |
| MC | Minicar |
| MV | Minivan |
| PU | Pickup |
| SS | Small SUV |
| * Heavy Duty Truck Class | |
| LH | Long haul |
| SH | Short haul |
| * Aviation | |
| GA | General aviation |
| PA | Passanger |

| | |
|---|---|
| * Technology Type | |
| AD | Advanced |
| CO | Conventional |
| FX | Flex-fuel |
| HY | Hybrid |
| IM | Improved |
| PH | Plug-in |
| SM | SmartWay |
| * Passanger Rail Category | |
| CO | Commuter |
| IC | Intercity |
| SS | Subways and Streetcars |

As discussed above the BY template includes an EB sheet tied to the EB workbook, both the BY and NT templates have SETUP and Commodity/Process declaration sheets. The NT SETUP tab is linked directly to the corresponding BY sheet for the commodity and device names to help ensure consistency. Separate Process Data loadsheets are provided for light duty vehicles (LDV), heavy duty vehicles (HDV) and off-highway (OH) use. The final sheet (ProcData_XPRCs ) defines the sector fuel and emissions tracking processes (XTRN<fuel>) that link the supply commodities to the Transportation sector, and is only found in the BY sheet. If new commodities not found in the original first year energy balance are needed for future years, as discussed in Section 6, the 0 on row-5 of the BY-TRN EB sheet for said fuel should be deleted, activating the fuel and associated XTRN<fuel> process.

The Transportation sector is handled the same as the rest of the EPA US9r referenced templates, in that the SETUP sheet controls what is/is not included for the sector, and the ProcData_TRN sheet links directly to their EPA_TRN counterpart via VLOOKUP, converting costs as specified on the SETUP sheet. A snapshot of the LDV load sheet is shown in Figure 36.

## Figure 36: New Light Duty Vehicles Loadsheet

| Proc STARTER | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Check Sheet | Name, ProcDesc, Units | | CommIN | CommOUT / LIFE | | START | INVCOST | INVCOST | INVCOST | INVCOST | INVCOST | INVCOST | EFF_I | EFF_I | EFF_I | EFF_I | EFF_I | EFF_I | FIXOM | | | | DISCRAT |
| Parameter | | | * | | NCAP_TLIF | NCAP_STA | NCAP_COS | NCAP_COS | NCAP_COS | NCAP_COS | NCAP_COS | NCAP_COS | ACT_EFF | ACT_EFF | ACT_EFF | ACT_EFF | ACT_EFF | ACT_EFF | NCAP_FOM | PRC_VINT | FLO_SHAR | FLO_SHAR | NCAP_DI |
| Qualifier1 | | | | | | | | | | | | | ACTGRP | ACTGRP | ACTGRP | ACTGRP | ACTGRP | ACTGRP | | | TRNBIOGSI | TRNBIOGSL | |
| Qualifier2 | | | | | | | | | | | | | ANNUAL | ANNUAL | ANNUAL | ANNUAL | ANNUAL | ANNUAL | | | ANNUAL | ANNUAL | |
| ProcName | ProcDesc | ProcUnits | CommIN | Con ti | | TID | 2013 | 2015 | 2025 | 2035 | 2045 | 2050 | 2013 | 2015 | 2025 | 2035 | 2045 | 2050 | | TID | | 0 | TID |
| * TECHNOLOGIES | | | | | | | | | | | | | | | | | | | | | | | |
| * Light Duty Vehicle Demand Technologies | | | | | | | | | | | | | | | | | | | | | | | |
| TLDMCOILGSL-C( | Transport: Light Duty Vehicles Minicar; Gasoline - Con | Bv-km,Bv-k | TRNOILGSL | TLD | 20 | 2010 | 5764.03 | 6952.34 | 7254.12 | 7256.31 | 7256.31 | 7256.31 | 0.2812 | 0.3022 | 0.4558 | 0.4570 | 0.4570 | 0.4570 | 61.5357 | 1 | | | 0.44 |
| TLDMCELC-PH1 | Transport: Light Duty Vehicles Minicar; Electricity - Plu | Bv-km,Bv-k | TRNELC | TLD | 20 | 2015 | 0.00 | 11017.55 | 8380.58 | 7795.15 | 7795.15 | 7795.15 | | 1.0261 | 1.0929 | 1.1225 | 1.1225 | 1.1225 | 46.1518 | 1 | | | 0.44 |
| TLDMCELC-PH2 | Transport: Light Duty Vehicles Minicar; Electricity - Plu | Bv-km,Bv-k | TRNELC | TLD | 20 | 2025 | 0.00 | 0.00 | 10538.62 | 9108.49 | 9108.49 | 9108.49 | | | 0.9089 | 0.9335 | 0.9335 | 0.9335 | 46.1518 | 1 | | | 0.44 |
| TLDCPOILGSL-C( | Transport: Light Duty Vehicles Compact; Gasoline - Co | Bv-km,Bv-k | TRNOILGSL | TLD | 20 | 2010 | 2805.72 | 2699.46 | 3026.16 | 3032.59 | 3032.59 | 3032.59 | 0.3239 | 0.3640 | 0.5400 | 0.5423 | 0.5423 | 0.5423 | 61.5357 | 1 | | | 0.44 |
| TLDCPELC-PH1 | Transport: Light Duty Vehicles Compact; Electricity - Pl | Bv-km,Bv-k | TRNELC | TLD | 20 | 2015 | 0.00 | 6530.02 | 4189.77 | 3662.29 | 3662.29 | 3662.29 | | 1.1328 | 1.2031 | 1.2368 | 1.2368 | 1.2368 | 46.1518 | 1 | | | 0.44 |
| TLDCPELC-PH2 | Transport: Light Duty Vehicles Compact; Electricity - Pl | Bv-km,Bv-k | TRNELC | TLD | 20 | 2025 | 0.00 | 0.00 | 6149.70 | 4853.97 | 4853.97 | 4853.97 | | | 1.0007 | 1.0286 | 1.0286 | 1.0286 | 52.7633596 | 1 | | | 0.44 |
| TLDCPOILDSL-C( | Transport: Light Duty Vehicles Compact; Diesel - Conv | Bv-km,Bv-k | TRNOILDSL | TLD | 20 | 2010 | 3232.99 | 3077.36 | 3185.87 | 3191.83 | 3191.83 | 3191.83 | 0.3990 | 0.4509 | 0.5765 | 0.5779 | 0.5779 | 0.5779 | 70.3511461 | 1 | | | 0.44 |
| TLDCPGASNAT-C | Transport: Light Duty Vehicles Compact; Natural Gas - | Bv-km,Bv-k | TRNGASNAT | TLD | 20 | 2010 | 3862.77 | 3641.30 | 3994.52 | 4001.87 | 4001.87 | 4001.87 | 0.3470 | 0.3936 | 0.5977 | 0.5996 | 0.5996 | 0.5996 | 63.3160315 | 1 | | | 0.44 |
| TLDCPGASNAT-F | Transport: Light Duty Vehicles Compact; Natural Gas - | Bv-km,Bv-k | TRNGASNAT<br>TRNOILGSL | TLD | 20 | 2010 | 3681.30 | 3459.25 | 3807.09 | 3814.43 | 3814.43 | 3814.43 | 0.3218 | 0.3659 | 0.5527 | 0.5544 | 0.5544 | 0.5544 | 63.3160315 | 1 | | | 0.44 |
| TLDCPOILDSL-HY | Transport: Light Duty Vehicles Compact; Diesel - Hybri | Bv-km,Bv-k | TRNOILDSL | TLD | 20 | 2020 | 0.00 | 0.00 | 3708.51 | 3628.91 | 3628.91 | 3628.91 | | | 0.6803 | 0.6821 | 0.6821 | 0.6821 | 73.8687034 | 1 | | | 0.44 |
| TLDCPBIOGSL-FX | Transport: Light Duty Vehicles Compact; Biogasoline - | Bv-km,Bv-k | TRNBIOGSL<br>TRNOILGSL | TLD | 20 | 2010 | 2916.52 | 2707.23 | 3034.93 | 3040.84 | 3040.84 | 3040.84 | 0.3250 | 0.3675 | 0.5457 | 0.5484 | 0.5484 | 0.5484 | 70.3511461 | 1 | | | 0.44 |
| * TLCFCH10 | TL.H2.C.FCH.2010 | Bv-km,Bv-k | TRNOILGSL | TLD | 20 | 2010 | 9669.89 | 8791.41 | 6732.07 | 5639.04 | 5639.04 | 5639.04 | 0.5880 | 0.5951 | 0.6157 | 0.6195 | 0.6195 | 0.6195 | 73.8687034 | 1 | | | 0.44 |
| TLDCPOILGSL-HY | Transport: Light Duty Vehicles Compact; Gasoline - Hyl | Bv-km,Bv-k | TRNOILGSL | TLD | 20 | 2010 | 3810.92 | 3302.66 | 3437.70 | 3357.92 | 3357.92 | 3357.92 | 0.5583 | 0.5174 | 0.7209 | 0.7236 | 0.7236 | 0.7236 | 73.8687034 | 1 | | | 0.44 |
| TLDCPOILLPG-FX | Transport: Light Duty Vehicles Compact; LPG - Flex-fu | Bv-km,Bv-k | TRNOILLPG<br>TRNOILGSL | TLD | 20 | 2010 | 3603.53 | 3376.49 | 3723.85 | 3730.87 | 3730.87 | 3730.87 | 0.3219 | 0.3659 | 0.5527 | 0.5547 | 0.5547 | 0.5547 | 63.3160315 | 1 | | | 0.44 |
| TLDCPOILGSL-PH | Transport: Light Duty Vehicles Compact; Gasoline - Plu | Bv-km,Bv-k | TRNOILGSL<br>TRNELC | TLD | 20 | 2010 | 3504.39 | 3398.13 | 3724.83 | 3731.26 | 3731.26 | 3731.26 | 0.8204 | 0.7603 | 1.0594 | 1.0634 | 1.0634 | 1.0634 | 73.8687034 | 1 | | | 0.44 |
| TLDFSOILGSL-C( | Transport: Light Duty Vehicles Fullsize; Gasoline - Con | Bv-km,Bv-k | TRNOILGSL | TLD | 20 | 2010 | 3320.91 | 3262.16 | 3575.01 | 3579.61 | 3579.61 | 3579.61 | 0.3085 | 0.3586 | 0.5365 | 0.5397 | 0.5397 | 0.5397 | 79.1450393 | 1 | | | 0.44 |

In addition, as discussed below, the vehicle type shares will need to be tailored to the country situation, where for example large cars, small cars, hybrids, etc. are all competing to provide passenger travel services. These shares are controlled by means of specifying the minimum or maximum percentage that each vehicle class (e.g., large (inefficient)) is projected to provide of the associated service demand.

Any Transportation component may be eliminated by entering "*" in Col-A on the SETUP sheet. If there is a need to add a new device type, do so by copying a similar type of vehicle's name on SETUP then Process data blocks on the appropriate ProcData_* sheets. Most of the names are carefully built from $references to their components, so after copying only minor adjustments need to be done to say change a fuel or technology instance. However, if adding a new technology there will be no corresponding data on the source data sheets, so the appropriate numbers will need to be provided. Also, be sure when adding an existing device not yet in the database that the device also gets added to the Calibration sheet appropriately (by copy/inserting a similar device in the same group).

> **Warning**: be sure to adhere to the basic naming convention of the components (that is use the same approach and number of characters as for some other entry) or the ANSWER named TechFilters and VBE Sets may no long operate properly!

### *5.4.6.1 Calibration of the Initial Year*

The Transportation sector is similar to the other sectors (other than Industry) in terms of preparing and performing the calibration. Below in Figure 37and Figure 38 the EB and Calibration sheets are shown, where the user input of the splits for the end-use services is done on the former and for the assciated devices on the latter. When entering the device splits when there is more than one competing device consuming a fuel, shares are requested for all but one of them, with the remaining share calculated to ensure the service/fuel total is respected. There are separate Calibration and loadsheets for light duty vehicles (LDVs) and the rest of the transportation demands.

## Figure 37: EB Sheet for Transportation

| | | | OILLPG | OILGSL | OILJET | OILKER | OILDSL | OILFOI | OILLUB | OILNSO | GASNAT | BIOGAS | BIOGSL | BIOJKE | BIODSL | ELC | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PJ | Sector Name | | LPG | Gasoline | Jet Fuel | Kerosene | Diesel | Fuel Oil | Lubricants | specified Oil Products | Natural Gas | Biogases | Biogasoline | Kerosene | Biodiesels | Electricity | All Energy |
| International marine bunkers | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| International aviation bunkers | 0 | | 0 | 0 | 3.6561 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3.6561 |
| **Transport** | **TRN** | | **0.0936** | **16.435** | **0.0306** | **0** | **17.127** | **0** | **0** | **0** | **1.965** | **0** | **0** | **0** | **0** | **1.0152** | **36.666** |
| Road | 0 | | 0.0936 | 16.4346 | 0 | 0 | 16.6816 | 0 | 0 | 0 | 1.965 | 0 | 0 | 0 | 0 | 0 | 35.1748 |
| Domestic aviation | 0 | | 0 | 0 | 0.0306 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0306 |
| Rail | 0 | | 0 | 0 | 0 | 0 | 0.3908 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.0152 | 1.406 |
| Pipeline transport | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Domestic navigation | 0 | | 0 | 0 | 0 | 0 | 0.055 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.055 |
| Non-specified (transport) | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Transport Services | | | | | | | | | | | | | | | | | |
| **Domestic aviation** | | | | | | | | | | | | | | | | | |
| **Final Energy Consumption for Domestic aviation** | | | | | | | | | | | | | | | | | |
| | **TAI** | **Transport: Air** | **0** | **0** | **0.0306** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0.03** |
| **Domestic navigation** | | | | | | | | | | | | | | | | | |
| **Final Energy Consumption for Domestic navigation** | | | | | | | | | | | | | | | | | |
| | **TSH** | **Transport: Ship** | **0** | **0** | **0** | **0** | **0.055** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0.06** |
| **Rail** | | | | | | | | | | | | | | | | | |
| **Share by service** | | | | | | | | | | | | | | | | | |
| | TRF | Transport: Rail - Freight | | | | | 50% | | | | | | | | | | |
| | TRP | Transport: Rail - Passanger | | | | | 50% | | | | | | | | | 100% | |
| | **Check 100%** | | **0%** | **0%** | **0%** | **0%** | **100%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **100%** | |
| **Final Energy Consumption for Rail services** | | | | | | | | | | | | | | | | | |
| | TRF | Transport: Rail - Freight | 0 | 0 | 0 | 0 | 0.1954 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0.20** |
| | TRP | Transport: Rail - Passanger | 0 | 0 | 0 | 0 | 0.1954 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.0152 | **1.21** |
| | **Total** | | **0** | **0** | **0** | **0** | **0.3908** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **1.0152** | **1.406** |
| | **Check diff from FEC** | | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
| **Road** | | | | | | | | | | | | | | | | | |
| **Share by service** | | | | | | | | | | | | | | | | | |
| Light Duty | | | | | | | | | | | | | | | | | |
| | TLD | Transport: Light Duty Vehicles | 70% | 50% | | | 50% | | | | 50% | | | | | | |
| Heavy Duty | | | | | | | | | | | | | | | | | |
| | TBU | Transport: Bus | | 10% | | | 10% | | | | 25% | | | | | | |
| | TMD | Transport: Medium Duty Trucks | 10% | 10% | | | 10% | | | | 10% | | | | | | |
| | THS | Transport: HDV Short Haul | 10% | 10% | | | 10% | | | | 15% | | | | | | |
| | THL | Transport: HDV Long Haul | 10% | | | | 10% | | | | | | | | | | |
| | TCT | Transport: Commercial Truck | | 20% | | | 10% | | | | | | | | | | |
| | **Check 100%** | | **100%** | **100%** | **0%** | **0%** | **100%** | **0%** | **0%** | **0%** | **100%** | **0%** | **0%** | **0%** | **0%** | **0%** | |
| **Final Energy Consumption for Road services** | | | | | | | | | | | | | | | | | |
| Light Duty | | | | | | | | | | | | | | | | | |
| | TLD | Transport: Light Duty Vehicles | 0.07 | 8.22 | - | - | 8.34 | - | - | - | 0.98 | - | - | - | - | - | **17.61** |
| Heavy Duty | | | | | | | | | | | | | | | | | |
| | TBU | Transport: Bus | - | 1.64 | - | - | 1.67 | - | - | - | 0.49 | - | - | - | - | - | **3.80** |
| | TMD | Transport: Medium Duty Trucks | 0.01 | 1.64 | - | - | 1.67 | - | - | - | 0.20 | - | - | - | - | - | **3.52** |
| | THS | Transport: HDV Short Haul | 0.01 | 1.64 | - | - | 1.67 | - | - | - | 0.29 | - | - | - | - | - | **3.62** |

## Figure 38: Calibration Sheet for Transportation

| Selected? | TRP | Transport: Rail - Passanger | Efficiency | Capacity Factor | Share of FEC | Final energy (PJ) | Demand (bn-pass-km) | Installed Capacity (bn-pass-km) | Fuel | Fuel share |
|---|---|---|---|---|---|---|---|---|---|---|
| | TRPOILDSL-CM-X0 | Transport: Rail - Passanger; Diesel - Commuter - Existing 0 | 1.015934108 | 1 | 1.00 | 0.1954 | 0.1985 | 0.20 | OILDSL | |
| | TRPOILDSL-IC-X0 | Transport: Rail - Passanger; Diesel - Intercity - Existing 00 | 0.621542356 | 1 | 0.00 | 0.0000 | 0.0000 | 0.00 | OILDSL | 0.88 |
| | | | | | 0.00 | 0.0000 | | | ELC | 0.12 |
| | TRPELC-CM-X0 | Transport: Rail - Passanger; Electricity - Commuter - Existir | 1.015934108 | 1 | 0.50 | 0.5076 | 0.5157 | 0.52 | ELC | |
| | TRPELC-SS-X0 | Transport: Rail - Passanger; Electricity - Subways and Stre | 1.83557863 | 1 | 0.50 | 0.5076 | 0.9317 | 0.93 | ELC | |
| | | | | | | **1.2106** | **1.6459** | **1.6459** | | |
| | | | | | from EB | 1.21 | | | | |
| | | | | | **check if zero** | **0.0000** | | | | |

| Selected? | TBU | Transport: Bus | Efficiency | Capacity Factor | Share of FEC | Final energy (PJ) | Demand (Bv-km) | Installed Capacity (Bv-km) | Fuel |
|---|---|---|---|---|---|---|---|---|---|
| | TBUOILDSL-X0 | Transport: Bus; Diesel - Existing 00 | 0.055953541 | 1 | 1.00 | 1.6682 | 0.0933 | 0.09 | OILDSL |
| | TBUOILGSL-X0 | Transport: Bus; Gasoline - Existing 00 | 0.060429824 | 1 | 1.00 | 1.6435 | 0.0993 | 0.10 | OILGSL |
| | TBUGASNAT-X0 | Transport: Bus; Natural Gas - Existing 00 | 0.047574025 | 1 | 1.00 | 0.4913 | 0.0234 | 0.02 | GASNAT |
| | | | | | | **3.8029** | **0.2160** | **0.2160** | |
| | | | | | from EB | 3.80 | | | |
| | | | | | **check if zero** | **0.0000** | | | |

| Selected? | TMD | Transport: Medium Duty Trucks | Efficiency | Capacity Factor | Share of FEC | Final energy (PJ) | Demand (Bv-km) | Installed Capacity (Bv-km) | Fuel |
|---|---|---|---|---|---|---|---|---|---|
| | TMDOILGSL-X0 | Transport: Medium Duty Trucks; Gasoline - Existing 00 | 0.095320218 | 1 | 1.00 | 1.6435 | 0.1567 | 0.16 | OILGSL |
| | TMDOILDSL-X0 | Transport: Medium Duty Trucks; Diesel - Existing 00 | 0.097424176 | 1 | 1.00 | 1.6682 | 0.1625 | 0.16 | OILDSL |
| | TMDGASNAT-X0 | Transport: Medium Duty Trucks; Natural Gas - Existing 00 | 0.07798367 | 1 | 1.00 | 0.1965 | 0.0153 | 0.02 | GASNAT |
| | TMDOILLPG-X0 | Transport: Medium Duty Trucks; LPG - Existing 00 | 0.085682657 | 1 | 1.00 | 0.0094 | 0.0008 | 0.00 | OILLPG |
| | | | | | | **3.5175** | **0.3353** | **0.3353** | |
| | | | | | from EB | 3.52 | | | |
| | | | | | **check if zero** | **0.0000** | | | |

| Selected? | THS | Transport: HDV Short Haul | Efficiency | Capacity Factor | Share of FEC | Final energy (PJ) | Demand (Bv-km) | Installed Capacity (Bv-km) | Fuel |
|---|---|---|---|---|---|---|---|---|---|
| | THSOILGSL-X0 | Transport: HDV Short Haul; Gasoline - Existing 00 | 0.081936407 | 1 | 1.00 | 1.6435 | 0.1347 | 0.13 | OILGSL |
| | THSOILDSL-X0 | Transport: HDV Short Haul; Diesel - Existing 00 | 0.063102882 | 1 | 1.00 | 1.6682 | 0.1053 | 0.11 | OILDSL |
| | THSGASNAT-X0 | Transport: HDV Short Haul; Natural Gas - Existing 00 | 0.063275756 | 1 | 1.00 | 0.2948 | 0.0187 | 0.02 | GASNAT |
| | THSOILLPG-X0 | Transport: HDV Short Haul; LPG - Existing 00 | 0.059628806 | 1 | 1.00 | 0.0094 | 0.0006 | 0.00 | OILLPG |
| | | | | | | **3.6157** | **0.2591** | **0.2591** | |
| | | | | | from EB | 3.62 | | | |
| | | | | | **check if zero** | **0.0000** | | | |

ANSv2-691-Home | SETUP | Commodities | EB | Calibration_LDV | Calibration_HDV&Off-road | CommData | Processes | ProcData_LDV

As discussed in Section 6, the work on the Calibration sheets in each BY workbook is the starting point for the calibration process. The cycle involves running the model (for just the first period if desired) and using the VBE calibration check workbook to see how well the model is aligning with the energy balance, returning to the BY Calibration sheets to devices shares assumptions as needed.

# 6 Calibration of the Base Year

The organization of the BY tempates was discussed in Section 2, including the basics of the Calibration sheet used for each sector to establish the technology mix according to the 1st year energy balance and local technologies in use today. This section provides details on the procedure to follow to calibrate the base year of the energy system as presented in TIMES, involving:

- checking that the first year resource supplies are properly reflected in the Supply workbook;
- establishing the power plant mix, and
- decomposing the energy balance for each demand sector to the service level and then establishing the existing techonology mix and contribution to meeting the service demand.

For all the sector workbooks two sheets are key to the calibration process: the energy balance (EB) sheet as carried across from the EB workbook for the sector, and the Calibration sheet where the work is done to decompose the sector level balance to the devices supplying the various end-uses, or in the case of the power sector the individual plant types. On each Calibration sheet there is a text box with instructions on completing its calibration. The essence of the process is to assign the percent of final energy fuel consumption associated with each of the end-use services on the EB sheet, and then apportion that down to the device level on the Calibration sheet. As the user enters these splits, the total within each group is cross-checked to ensure a good cailibration to the energy balance. But once setup the model needs to be run (for only the 1st period is fine) to see if the input splits et al provided indeed align with what is produced from the model. Troubleshooting differences between the original EB and that obtained from a model run is discussed in the next section.

To faciliate this comparison a VBE UpdateXLS workbook has been setup with tables corresponding to:

- resource supply by source and fuel type;
- power, CHP and heating plants consumption and generation by fuel type, and
- final energy consumption by sector and fuel.

These VBE dump tables, shown in Figure 39, are processed using VLOOKUP functions on the EB fuel/sector names to assemble the information on the EB Results sheet and assembled on the EB Results sheet (Figure 40), then said values are compared against the original EB (Figure 41) and the power sector details (Figure 42) to see that these are in alignment. The EB & PP_Calib Check sheets show any differences, which then need to be tracked down and resolved, as discussed in the next section.

| |
|---|
| **Note**: If the names/structure of the EB or the BY-PP calibration sheet are changed, the Calibration Check workbook needs to be adjusted accordingly. |

## Figure 39: Calibration VBE UpdateXLS Dump Tables

| Table Name: Calib - Final Energy Consumption (by Sec & Fu | | |
|---|---|---|
| Active Unit: PJ | | |
| Scenario | Commodity\Period | 2013 |
| REF-09 | AGRBIOPSF | 0.0018 |
| REF-09 | AGRELC | 0.1246 |
| REF-09 | AGRGASNAT | 0.0588 |
| REF-09 | AGROILDSL | 3.53E-01 |
| REF-09 | AGROILGSL | 3.62E-02 |
| REF-09 | COMBIOPSF | 3.36E-01 |
| REF-09 | COMCOAANT | 1.30E-02 |
| REF-09 | COMCOALIG | 0.0053 |
| REF-09 | COMELC | 4.3256 |
| REF-09 | COMGASNAT | 2.8712 |
| REF-09 | COMLTH | 1.269 |
| REF-09 | COMOILFOI | 0.1794 |
| REF-09 | COMOILLPG | 0.0134 |
| REF-09 | COMRNWGEO | 0.312 |
| REF-09 | COMRNWSOL | 2.34E-02 |
| REF-09 | INDBIOPSF | 9.00E-03 |
| REF-09 | INDCOAANT | 0.219 |
| REF-09 | INDCOALIG | 6.9236 |
| REF-09 | INDCOAOBC | 1.76 |
| REF-09 | INDCOAORG | 4.258 |
| REF-09 | INDELC | 14.1582 |
| REF-09 | INDGASNAT | 2.9157 |
| REF-09 | INDOILDSL | 2.49E+00 |
| REF-09 | INDOILFOI | 5.30E-02 |
| REF-09 | INDOILGSL | 3.75E-01 |
| REF-09 | INDOILKER | 9.30E-03 |
| REF-09 | RSDBIOPSF | 19.7987 |
| REF-09 | RSDCOALIG | 0.051 |
| REF-09 | RSDELC | 13.0463 |
| REF-09 | RSDGASNAT | 27.7172 |
| REF-09 | RSDLTH | 6.10E+00 |
| REF-09 | RSDOILKER | 8.60E-03 |
| REF-09 | RSDOILLPG | 0.639 |
| REF-09 | RSDRNWSOL | 0.0233 |
| REF-09 | TRNELC | 1.0152 |
| REF-09 | TRNGASNAT | 1.965 |
| REF-09 | TRNOILDSL | 17.1274 |
| REF-09 | TRNOILGSL | 1.64E+01 |
| REF-09 | TRNOILJET | 3.06E-02 |
| REF-09 | TRNOILLPG | 9.36E-02 |

| Table Name: Calib - Electric Generation (by Type) | | | |
|---|---|---|---|
| Active Unit: PJ | | | |
| Scenario | ProcessSetDesc | Process\Period | 2013 |
| REF-09 | Biofuel-fired | EEBIOGAS-CC-X | 0.25 |
| REF-09 | Biofuel-fired | EEBIOGAS-EN-X | 0.5 |
| REF-09 | Biofuel-fired | EEBIOGAS-GT-X | 0.5 |
| REF-09 | Biofuel-fired | EEBIOGAS-ST-X | 0.24894 |
| REF-09 | Biofuel-fired | EEBIOMSW-ST-: | 1 |
| REF-09 | Biofuel-fired | EEBIOPSF-IG-XC | 5.683107 |
| REF-09 | Biomass fired CHP | EHBIOPSF-ST-X | 0.769231 |
| REF-09 | Coal fired CHPs | EHCOAANT-ST-: | 1.3 |
| REF-09 | Coal-fired | EECOALIG-IG-XC | 3 |
| REF-09 | Coal-fired | EECOALIG-ST-X | 4.5 |
| REF-09 | Coal-fired | EECOAOBC-ST-: | 1.5 |
| REF-09 | Coal-fired | EECOASBC-ST-: | 1.5 |
| REF-09 | Gas fired CHPs | EHGASNAT-CC-: | 1.428571 |
| REF-09 | Gas fired CHPs | EHGASNAT-EN-: | 0.909091 |
| REF-09 | Gas-fired | EEGASNAT-CC-: | 3 |
| REF-09 | Gas-fired | EEGASNAT-CT-: | 3.3552 |
| REF-09 | Hydro | EERNWHYD-DM- | 1.5 |
| REF-09 | Hydro | EERNWHYD-RR- | 0.5 |
| REF-09 | Nuclear | EENUCLER-LWF | 1 |
| REF-09 | Other Renewables | EERNWGEO-ST- | 0.5 |
| REF-09 | Other Renewables | EERNWSOL-TC- | 1 |
| REF-09 | Other Renewables | EERNWWIN-OF- | 0.5 |
| REF-09 | Other Renewables | EERNWWIN-ON- | 1 |
| REF-09 | Total | | 35.44414 |

| Table Name: Calib - Heat Generation (by Type) | | | |
|---|---|---|---|
| Active Unit: PJ | | | |
| Scenario | ProcessSe | Process\P | 2013 |
| REF-09 | Biomass f | EHBIOPS | 2 |
| REF-09 | Biomass f | HPBIOPS | 1 |
| REF-09 | Coal fired | EHCOAAN | 1.69 |
| REF-09 | Electricity | HPELC-BI | 0.499 |
| REF-09 | Electricity | HPELC-HI | 0.5 |
| REF-09 | Gas fired | EHGASNA | 1 |
| REF-09 | Gas fired | EHGASNA | 1 |
| REF-09 | Gas fired | HPGASNA | 0.5 |
| REF-09 | Total | | 8.189 |

| Table Name: Calib - HPL Fuel Consumption | | | |
|---|---|---|---|
| Active Unit: PJ | | | |
| Scenario | Process | Commodit | 2013 |
| REF-09 | HPBIOPS | PWRBIOF | 0.99 |
| REF-09 | HPELC-BI | PWRELC | 0.52894 |
| REF-09 | HPELC-HI | PWRELC | 0.19 |
| REF-09 | HPGASNA | PWRGAS | 0.5 |

| Table Name: Calib - CHP Fuel Consumption | | | |
|---|---|---|---|
| Active Unit: PJ | | | |
| Scenario | Process | Commodit | 2013 |
| REF-09 | EHBIOPS | PWRBIOF | 4 |
| REF-09 | EHCOAAN | PWRCOA | 5 |
| REF-09 | EHGASNA | PWRGAS | 4 |
| REF-09 | EHGASNA | PWRGAS | 5.222 |

EB_Check | PP_calib_check | EB | BY-PP | VBE_tables | EB_results

## Figure 40: Calibration Results EB Table

**EB constructed from model results**

**Country (Region) Name** **STARTER**

| | | BIOMSW | BIOPSF | BIOGAS | BIOGSL | BIOJKE | BIODSL | BIOCHA | NUCLER | RNWHYD | RNWGEO | RNWSOL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PJ** | **Sector Name** | Municipal Waste | Primary Solid Biofuels | Biogases | Biogasoline | Bio Jet Kerosene | Biodiesels | Charcoal | Nuclear | Hydro | Geothermal | Solar |
| Production | | 5.56 | 47.86 | 4.85 | | | | | | 2.00 | 1.87 | 1.05 |
| Imports | | | | | | | | | 2.94 | | | |
| Exports | | - | - | - | - | - | - | - | - | - | - | - |
| International marine bunkers | | - | - | - | - | - | - | - | - | - | - | - |
| International aviation bunkers | | - | - | - | - | - | - | - | - | - | - | - |
| Stock changes | | - | - | - | - | - | - | - | - | - | - | - |
| **Total primary energy supply** | | **5.56** | **47.86** | **4.85** | **-** | **-** | **-** | **-** | **2.94** | **2.00** | **1.87** | **1.05** |
| Transfers | | - | - | - | - | - | - | - | - | - | - | - |
| Statistical differences | | 0.000 | 0.000 | 0.000 | - | - | - | - | 0.000 | - | -0.000 | -0 |
| **Transformation Processes and Losses** | | **-5.56** | **-27.71** | **-4.85** | **-** | **-** | **-** | **-** | **-2.94** | **-2.00** | **-1.56** | **-1.00** |
| Main activity producer electricity plants | PWR | -5.56 | -22.72 | -4.85 | | | | | -2.94 | -2.00 | -1.56 | -1.00 |
| District CHP plants | PWR | | -4.00 | | | | | | | | | |
| District heat only plants | PWR | | -0.99 | | | | | | | | | |
| Losses (from pipelines and transmission) | | | | | | | | | | | | |
| **Final consumption** | | **-** | **20.15** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **0.31** | **0.05** |
| **Industry** | **IND** | **-** | **0.01** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** |
| **Transport** | **TRN** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **-** |
| **Other** | | **-** | **20.14** | **-** | **-** | **-** | **-** | **-** | **-** | **-** | **0.31** | **0.05** |
| Residential | RSD | - | 19.80 | - | - | - | - | - | - | - | - | 0.02 |
| Commercial | COM | - | 0.34 | - | - | - | - | - | - | - | 0.31 | 0.02 |
| Agriculture | AGR | - | 0.00 | - | - | - | - | - | - | - | - | - |
| Fishing | AGR | | | | | | | | | | | |
| Non-specified (other) | | | | | | | | | | | | |

EB_Check | PP_calib_check | EB | BY-PP | VBE_tables | EB_results

## Figure 41: Calibration EB Comparison Table

| Differences between EB and model resu | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ountry (Region) Nam | STARTER | | | | | | | | | | | | |
| | | OILDSL | OILFOI | OILNAP | OILLUB | OILBIT | OILPCO | OILNSO | GASNAT | BIOIWA | BIOMSW | BIOPSF | BIOGAS |
| PJ | Sector Name | Diesel | Fuel Oil | Naphtha | Lubricants | Bitumen | Petroleum Coke | Other Oil Products (excluding non-energy uses) | Natural Gas | Industrial Waste | Municipal Waste | Primary Solid Biofuels | Biogases |
| Production | | - | - | - | - | - | - | - | 0.00 | - | - | - | 0.00 |
| Imports | | - | - | - | - | - | - | - | - | - | - | - | - |
| Exports | | - | - | - | - | - | - | - | - | - | - | - | - |
| International marine bunkers | | - | - | - | - | - | - | - | - | - | - | - | - |
| International aviation bunkers | | - | - | - | - | - | - | - | - | - | - | - | - |
| Stock changes | | - | - | - | - | - | - | - | - | - | - | - | - |
| **Total primary energy supply** | | - | - | - | - | - | - | - | 0.00 | - | - | - | 0.00 |
| Transfers | | - | - | - | - | - | - | - | - | - | - | - | - |
| Statistical differences | | 0.000 | -0.000 | - | - | - | - | - | 0.000 | - | -0.000 | -0.000 | -0.000 |
| **Transformation Processes and Losses** | | - | - | - | - | - | - | - | -0.00 | - | -0.00 | -0.00 | -0.00 |
| Main activity producer electrici | PWR | - | - | - | - | - | - | - | -0.00 | - | -0.00 | -0.00 | -0.00 |
| District CHP plants | PWR | - | - | - | - | - | - | - | -0.00 | - | - | -0.00 | - |
| District heat only plants | PWR | - | - | - | - | - | - | - | 0.00 | - | - | 0.00 | - |
| Losses (from pipelines and transmission) | | - | - | - | - | - | - | - | - | - | - | - | - |
| **Final consumption** | | -0.00 | 0.00 | - | - | - | - | - | 0.00 | - | - | 0.00 | - |
| **Industry** | **IND** | 0.00 | 0.00 | - | - | - | - | - | 0.00 | - | - | 0.00 | - |
| **Transport** | **TRN** | -0.00 | - | - | - | - | - | - | 0.00 | - | - | - | - |
| **Other** | | - | - | - | - | - | - | - | 0.00 | - | - | - | - |
| Residential | RSD | - | - | - | - | - | - | - | 0.00 | - | - | - | - |
| Commercial | COM | - | - | - | - | - | - | - | 0.00 | - | - | - | - |
| Agriculture | AGR | - | - | - | - | - | - | - | - | - | - | - | - |
| Fishing | AGR | - | - | - | - | - | - | - | - | - | - | - | - |
| Non-specified (other) | | - | - | - | - | - | - | - | - | - | - | - | - |

EB_Check | PP_calib_check | EB | BY-PP | VBE_tables | EB_results

## Figure 42: Calibration PP Comparison Table

| selected | | Checking Calibration of power and heat generation | Fuel | Fuel consumption | | | Electricity Produced | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | From BY-PP | From Results | DIFF (check if 0) | Est/known elc prod | From Results | DIFF (check if 0) |
| | **Electricity Only Power Plants** | | | PJ | | | PJ | | |
| | * Hydro | | | | | | | | |
| | EERNWHYD-DM-X0 | Hydro (Dam) (Existing) | PWRRNWHYD | 1.5 | 1.5 | 0.0 | 1.5 | 1.5 | 0.0 |
| | EERNWHYD-RR-X0 | Hydro (Run-of-River) (Existing) | PWRRNWHYD | 0.5 | 0.5 | 0.0 | 0.5 | 0.5 | 0.0 |
| * | EERNWHYD-PS-X0 | Hydro (Pumped Storage) (Existing) | PWRRNWHYD | | | | | | |
| * | | | PWRELC | | | | | | |
| | | Total | | 2 | | | 2 | | |
| | * Gas | | | | | | | | |
| | EEGASNAT-CC-X0 | Natural Gas - Combined cycle (Existing) | PWRGASNAT | 6.67 | 6.7 | 0.0 | 3 | 3.0 | 0.0 |
| | EEGASNAT-CT-X0 | Natural Gas - Combustion turbine (Existing) | PWRGASNAT | 11.98 | 12.0 | 0.0 | 3.3552 | 3.4 | 0.0 |
| | | Total | | 18.65 | | | 6.3552 | | |
| | * Coal | | | | | | | | |
| | EECOAOBC-ST-X0 | Bituminous (Brown Coal) - Steam turbine (Existing) | PWRCOAOBC | 4.59 | 4.6 | 0.0 | 1.5 | 1.5 | 0.0 |
| | EECOASBC-ST-X0 | Sub-Bituminous Coal - Steam turbine (Existing) | PWRCOASBC | 4.5 | 4.5 | 0.0 | 1.5 | 1.5 | 0.0 |
| | EECOALIG-ST-X0 | Lignite - Steam turbine (Existing) | PWRCOALIG | 13.64 | 13.6 | 0.0 | 4.5 | 4.5 | 0.0 |
| | EECOALIG-IG-X0 | Lignite - Integrated Gasif. (Existing) Combined cycle | PWRCOALIG | 8.57 | 8.6 | 0.0 | 3 | 3.0 | 0.0 |
| | | Total | | 31.3 | | | 10.5 | | |
| | * Nuclear | | | | | | | | |
| | EENUCLER-LWR-X0 | Nuclear - LWR (Existing) | PWRNUCLER | 2.94 | 2.9 | 0.0 | 1 | 1.0 | 0.0 |

EB_Check | PP_calib_check | EB | BY-PP | VBE_tables | EB_results

## 6.1 Common Reasons and Remedies for Calibration Issues

Carefully checking all EB and Calibration sheets before running the model will minimize the chances of mis-calibration of initial year. Before checking the BY template calibration make sure that all the dependent templates are linked properly and have been updated (opened and saved) to ensure all children are "younger" than their parents.

First, make sure that "Check if 100%", and "Check diff from FEC" yield correspondingly either 100% or 0 on sector "EB" sheets. If this is not the case, then the splits entered in the "split by end-use" section of each Calibration sheet are incorrect and need to be adjusted to ensure they sum to 100% or align with the FEC from the EB. The only exception from the "Check if 100%" rule is getting 0% instead of 100% for those energy commodities that are not consumed in corresponding sector at all.

Afterwards the "Calibration" sheet needs to be checked to ensure and make sure that the sum of "Share of FEC" for all technologies consuming the same fuel within the same end-use commodity is equal to 1. Also make sure that fuel consumption is not assigned to a process which has "*" in column A. Then, carefully look at the "Check if 0" cells to make sure that all values are equal to zero. If one is not, and if the checks above are all correct, the most likely reason for mis-calibration is that some fuel has been assigned to this end use in the EB sheet "split by end-use" section, but the list of technologies in "calibration" sheet" doesn't have a technology consuming this fuel.

For example, you may have geothermal energy use in residential water heating category in your model, but the current TIMES-Starter model does not have a geothermal-consuming technology in its list of available technologies for water heating, so the EB check will fail. The procedure for adding a new device is discussed in Section 14. In this case the corresponding technology needs to be added or the EB adjusted.

A similar case may occur during calibration of power sector (i.e. your EB has a plant consuming some fuel which is not listed in the TIMES-Starter technology list). But in this case you are notified that you are missing the plant using a specific fuel by the zero value in "from Calibration" section in EB sheet, whereas the "From Balance" section does have a value assigned for that fuel and power plant type. This will also result in non-zero values in the "Difference (check if zero)" section. Alternatively, these non-zero values may be an indication that fuel consumption and/or generation values on Calibration sheet have not been split correctly between different power plants. In this case please carefully check the Calibration sheet again.

Despite the care taken when filling the BY templates, it is not an unusual situation that the model results do not perfectly calibrate after the first runs of the model. As discussed above, use the CalibrationCheck VBE UpdateXLS workbook to examine which sectors and fuels are off. Always start checking the calibration with the demand sectors, moving backward through the RES, because calibration of power and supply sectors will not be possible until the demand sectors are all properly calibrated.

In all sectors, some common oversights or pitfalls to avoid include making sure that:

- as noted above, all child templates are younger than their parents;
- the calibration checks listed above have been performed and are correct;
- the values in the template align with those one sees in ANSWER, that is that the latest version of the template is indeed the one currently in the database;
- there is no UC in the current run that affects the end-use or power plant technologies in the BY, and
- only the scenarios relevant for the calibration are loaded in the Run form, that they are in the correct order, and that nothing overrides the 1$^{st}$ year values.

In addition to these general reminders, when considering the possible reasons for mis-calibration in the different sectors keep in mind that it may be the case that while focusing on a particular technology the mis-calibration may be due to something wrong with another technology in the same sector. The sections that follow discuss what may be the cause of an imbalance together with suggestions for how to go about determining the reasons and correcting them.

### 6.1.1 Mis-calibration in demand sectors

If mis-calibration is observed in the demand sectors, some possible reasons are noted below.

- Incorrect parameters have been used for one or more of the end-use technologies which can be either due to incorrect formulas in calibration, or the mismatch of parameter values in templates and the model scenarios. Try to figure out those technology (ies) that are causing mis-calibration. To do so, use ANSWER-TIMES and/or VEDABE and check all technologies consuming the affected fuel in the affected sector. To find which technology is causing the mis-calibration compare the final energy consumption values from model results with the "Final Energy" values in sectoral "calibration" sheets. They should be the same. After locating the technology responsible for mis-calibration do the following:
    - Carefully check the formulas for the affected technology in the calibration sheet and make sure that the values that are calculated there are those that are read by "ProcData" sheets. If you haven't made any changes to EB calibration and ProcData sheets, this generally shouldn't be the cause. Check separately bi-fuel or bi-enduse technologies, because the formulas for their calibration differ from formulas used for "standard" technologies. After finding the error – correct it.
    - Compare the values of parameters for the affected technology with those that are in the corresponding ANSWER-TIMES scenario, by selecting this scenario in ANSWER-TIMES (locating it in right hand upper window of ANSWER-TIMES console) and browsing the values for that technology. Make sure that the last version of template was read in the model. If values differ – reimport the Scenario. Also make sure that no other scenario changes the value of parameters and that if there is a scenario that changes the values it is not used in the current run overriding the BY-scenario of that sector.
- Make sure to have the correct end-use demand specified for the 1st period as obtained from the calibration workbook reflected in the Demand workbook and ANSWER.
- If the affected commodity is electricity or heat, the reason for mis-calibration may be due to incorrect COM_FRs. Check that the latest COM_FRs in the model database align with what is in the template and ANSWER.
- Dual fuel or service devices fixed shares need to be adjusted.
- Mis-calibration of end-use technologies can be also due to mis-calibration of upstream RES, i.e. power system and supply system (i.e. not enough fuel is coming from supply sector), discussed below.

### 6.1.2 Mis-calibration in power sector

The list bellow discusses the possible reasons for mis-calibration in power sector and the ways to remedy them.

- Make sure that there is no base year bound on the plant in PP-data affecting the behavior of the plant.

- Make sure that the latest year timeslices (G_YRFRs) are in the model database.
- Dual fuel plants with fixed ratios for the shares are not in the correct proportions, and need to be adjusted.
- CHP electricity to heat ratios are not in the correct proportions, and need to be adjusted.
- Mis-calibration of power plants may be due to mis-calibration of demand sectors (which should be corrected first) or the supply system including grids, which is discussed below.

### 6.1.3 Mis-calibration of supply system

If mis-calibration is due to the supply system the most likely reason will be the bounds on supply technologies, which come from the EB for the first period. For grids they are "built" (at no cost) according to the EB levels and a user provided utilization factor. Please check all the bounds on the supply and grid technologies in templates and in the model database. Also make sure that there is no scenario overriding the values.

You need to also make sure that there is a supply option for all energy carriers active in the energy balance in the initial period. An indication that there is none, or that the supply is not enough, is that the ZZBCKNRG backstop process enters the model results in the first period. To handle this type of mis-calibration you need to add the supply technology or change/remove the bounds.

# 7 Managing Scenarios in ANSWER and Submitting a Model Run

The ANSWERv6-TIMES Getting Started & User Manuals provide detailed documentation on all aspects of working with ANSWER-TIMES. Here brief guidelines for managing the Starter model via ANSWER-TIMES are presented.

## 7.1 Handling Updates

Changes are part of the game and when new versions of the various components of the TIMES modeling platform are announced by the developers, or an update to the US9r database is released, the user should move to apply these updates to their system. Before doing so it is always advisable to back your all model files!

When new versions of GAMS, ANSWER and/or VBE are released the update procedures (or in the case of GAMS, new distribution) should be followed and the system updated. In most all cases there will be no impact on your model directly. The one exception is where there is an update of the TIMES GAMS code (in the GAMS_SrcTI folder). After introducing the update it is recommended that the standard Template.GEN file be augmented to include the *GG* block of lines below, if not found in the file. These switches adjust the handling of aspects of the objective function and aspects of the reporting (see the TIMES documentation) that best suit that TIMES-Starter model.

```
*GG* Add the LevelizedCost/Cost_NPV switches
$ SET ANNCOST LEV
$ SET OBJ AUTO
$ SET OBLONG YES
$ SET MID_YEAR YES
$ SET RPT_OPT NCAP.1 -1
```

When a new release of the USEPA US9r technology database[12] is released, ETSAP will update the TIMES-Starter model templates and make new templates available to all users. Those with existing models assembled from TIMES-Starter will only need to consider US9r updates to the SUP and NT templates in terms of introduction and changes in international energy prices and new technology characterizations. To this end, USEPA will provide a fairly detailed list of any changes made including identifying any new technologies added. The TIMES-Starter version of these changes should be able to be introduced into your model directly by simply copying the version distributed over that being used in your templates model to adopt any updates. If EPA has added new technologies then your NT templates will need to be manually updated carefully by copying the SETUP/declaration/data sheets from the new TIMES-Starter into your templates after moving in the new EPA sheet.

In terms of managing your own templates, the approach recommended is to copy and rename your ANSWER_Databases\TIMES-Starter(country)_vXX folder to a new version, perhaps also renaming the MDB in said new folder. This will ensure that all the scenario/template mappings for the ANSWER ImportXLS operation remain intact and correct, as discussed in the next section. Note that the Calibration and AnalyticsXLS result handling workbooks are also retained in this folder and one may want to increment their version numbers with that of the new folder.

## 7.2 Aligning Templates with Scenarios

As presented in the previous sections, there are a number of ANSWER-TIMES "Smart" Excel workbooks that accompany this TIMES-Starter database. The full set of templates comprise a Starter model, and consist of three types of templates:

- AT_ "Smart" v1 templates where either commodity groups, IRE processes, or user constraints are assembled, or single parameter values set;
- AT2_ "Smart" v2 falling into three categories, Demand projection workbooks, Existing and New technologies, and
- S_ scenario workbooks which in some cases just carry out calculations or with a VBE ExportXLS table to grab Reference scenario results any apply policy targets, for example emissions, or power sector generation, or final energy consumption to evaluate emission reduction levels, renewable portfolio standards, or energy efficiency improvement. [Note that in some cases the S_scenario is easier to simply setup in ANSWER without an associated workbook, e.g., to test a higher price for nuclear power plants.]

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[12] Note that to date there have not been any updates to the US9r database since the development of the TIMES-Starter model, so it is possible that these instructions may change somewhat after the first updated expected in October 2016.

The templates comprising the TIMES-Starter (that is EB, SUP, all BY/NT<sect>, Demand and UC<sect>) have been discussed in the previous sections or are elaborated in the sections that follow. Each of the templates has an associated Scenario in ANSWER into which it is to be loaded (at times more than one template may be in a scenario) as discussed below. The Scenario/Template alignment is shown in Figure 43. All the templates are kept in the same folder as the ANSWER database to facilitate version control. When looking to freeze a current model instance, the entire folder can be copied, perhaps appending the date. This enables the ANSWER import templates "Same Folder" option, discussed in the next section, to be employed.

All the templates comprising the TIMES-Starter model have a Country field on the SETUP sheet which links to the associated EB workbook (which will enable the TIMES-Starter to accommodate multi-region models).

**Figure 43: Scenario/Templates Alignment**

| Starter Model Templates & Scenarios | | |
|---|---|---|
| Name | Description | Reference Scenarios |
| BASE | BASE scenario | Globals/Timeslices – manually entered from EB |
| BOUNDLO | Impose lower bounds on operation of selected existir | REF_BOUNDLO |
| BOUNDLO-RED | Reduced lower bounds on operation of selected exis | REF_BOUNDLO-RED |
| BY-AGR | BY Agriculture | AT2_Starter_BY-AGR |
| BY-COM | BY commercial | AT2_Starter_BY-COM |
| BY-IND | BY-Industry (dummy) | AT2_Starter_BY-IND |
| BY-PP | BY Power Sector | AT2_Starter_BY-PP |
| BY-RSD | BY residential | AT2_Starter_BY-RSD |
| BY-TRN | BY Transport | AT2_Starter_BY-TRN |
| DEMAND-REF | Demand Projections REF | AT2_Starter_Demand-REF |
| NT-AGR | New Agriculture Devices | AT2_Starter_NT-AGR |
| NT-COM | New Commercial Devices | AT2_Starter_NT-COM |
| NT-PP | New Power Plants | AT2_Starter_NT-PP |
| NT-RSD | New Residential Devices | AT2_Starter_NT-RSD |
| NT-TRN | New Transport Vehicle | AT2_Starter_NT-TRN |
| S_CO2LIM20 | Limit on CO2 Emissions (10% in 2020 to 20% in 2050) | S_CO2-20 |
| S_CO2LIM30 | Limit on CO2 Emissions (15% in 2020 to 30% in 2050) | S_CO2-30 |
| S_CO2LIM40 | Limit on CO2 Emissions (15% in 2020 to 40% in 2050) | S_CO2-40 |
| | | S_CO2-50 |
| S_CO2TAX | CO2 Tax | S_CO2TAX |
| S_GHGLIM20 | Limit on CO2EQ Emissions (10% in 2020 to 20% in ... | Scen_GHG-20 |
| S_LIMFEC | Limit on Final Energy Consumption (15% in 2030) | Scen_LIMFEC |
| S_LIMFELC | Limit Final Electrcity Consumption | Scen_LIMFELC |
| S_RPS | Renewable Electricity Share | Scen_RPS |
| SUP | Supply | AT_Starter_Supply |
| TECH-BOUND | Limits on capacity of new technologies | ANSWER scenario (no XLS) |
| UC-COM | Reference Guidance Constraints for COM | AT_UC-COM |
| UC-COM50 | Loosened Guidance Constraints for COM - 50% | AT_UC-COM-50 |
| UC-COM90 | Loosened Guidance Constraints for COM | AT_UC-COM-90 |
| UC-RSD | Reference Guidance Constraints for RSD | AT_UC-RSD |
| UC-RSD50 | Loosened Hi EFF Guidance Constraints for RSD - ... | AT_UC-RSD-50 |
| UC-RSD90 | Loosened Hi EFF Guidance Constraints for RSD | AT_UC-RSD-90 |
| UC-TRN | Reference Guidance Constraints for TRN | AT_UC-TRN |
| UC-TRN50 | Loosened Hi EFF Guidance Constraints for TRN - ... | AT_UC-TRN-50 |
| UC-TRN90 | Loosened Hi EFF Guidance Constraints for TRN | AT_UC-TRN-90 |
| XIND-UC | Industry Fuel & Service Shares (pending) | pending |
| XNT-IND | New Industrial Processes (pending) | pending |
| ZZDMY | Backstops ZZDMY for DEM/NRG/ELC | AT_Starter_ZZDMY |

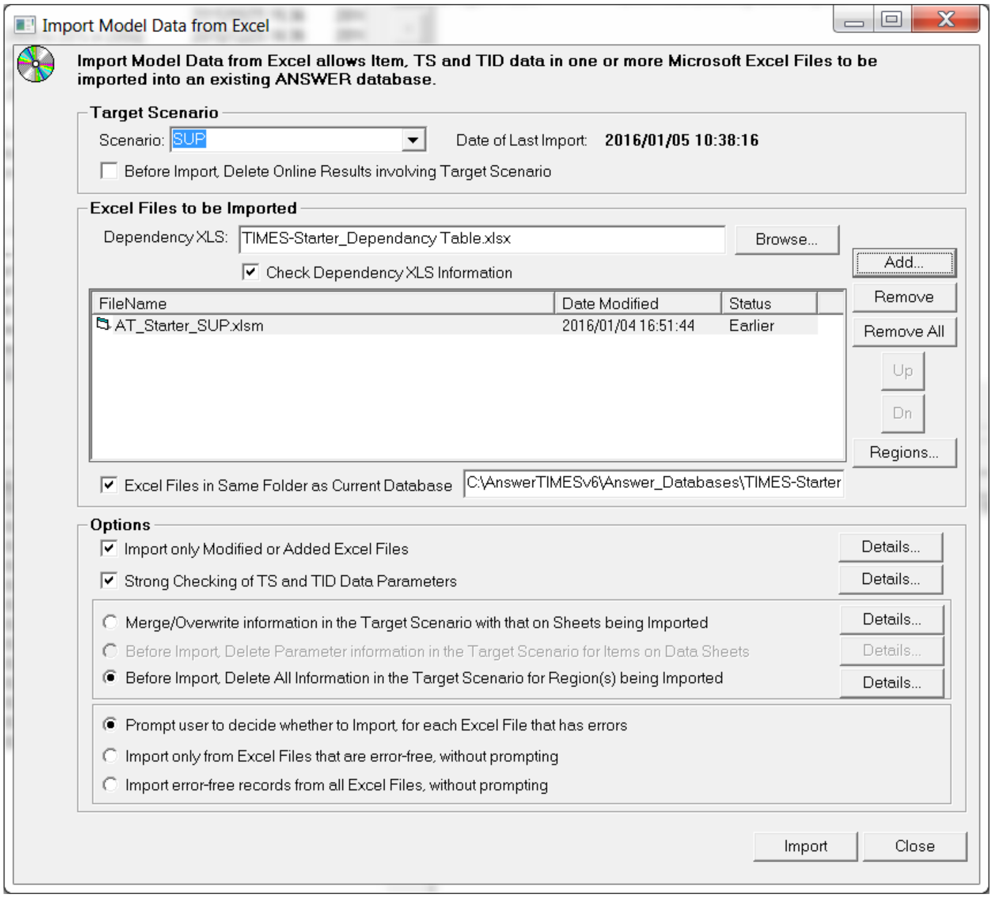
## 7.3 Importing Templates into ANSWER

The ANSWER File/Import/Model Data from Excel option [Ctrl-I] can be used to bring the templates into their associated Scenario. An example for New Power Plants is shown in Figure 44. Some particular things to note in terms of the switches on the Import template include:

- Pay careful attention to the Target Scenario to make sure you're loading into the correct scenario;
- The list of FileNames to be imported (one file for each other than Industry and Demands at this time) indicates when the associated template(s) was imported and whether said template is newer (later) or already in the database (earlier), where only the former will be imported, unless the "Only Modified/Added" Option is unchecked;
- For all scenarios (other the BASE, which is handled manually) the “Delete Before Importing” option should be employed to "clean out" the existing information in the scenario prior to importing, and
- For those scenarios consisting of more than one template, the scenario data from templates not being updated may or may not be consistent with the updated data. The “Before Import Delete Results” switch is a reminder that depending upon the nature of the changes made, the user should decide whether they want to dump all associated data, or not, when importing. Thus the safe thing to do is to import (force if necessary) all the templates associated with a scenario. If importing more than one template into a single scenario and only one of them has been changed, the Import only Modified or Added Excel Files must be UNCHECKED so that the "Earlier" template(s) will also be re-imported as part of the scenario.

Note the checked Check Dependency Information and specification of the workbook with the dependency table, as shown in Table 2 and discussed in Section 2. Should any Child which is older than its Parent(s) be reported in the log, it is recommended that these be opened and resaved prior to importing any such potentially out of synch template.

Figure 44: ANSWER Template Import



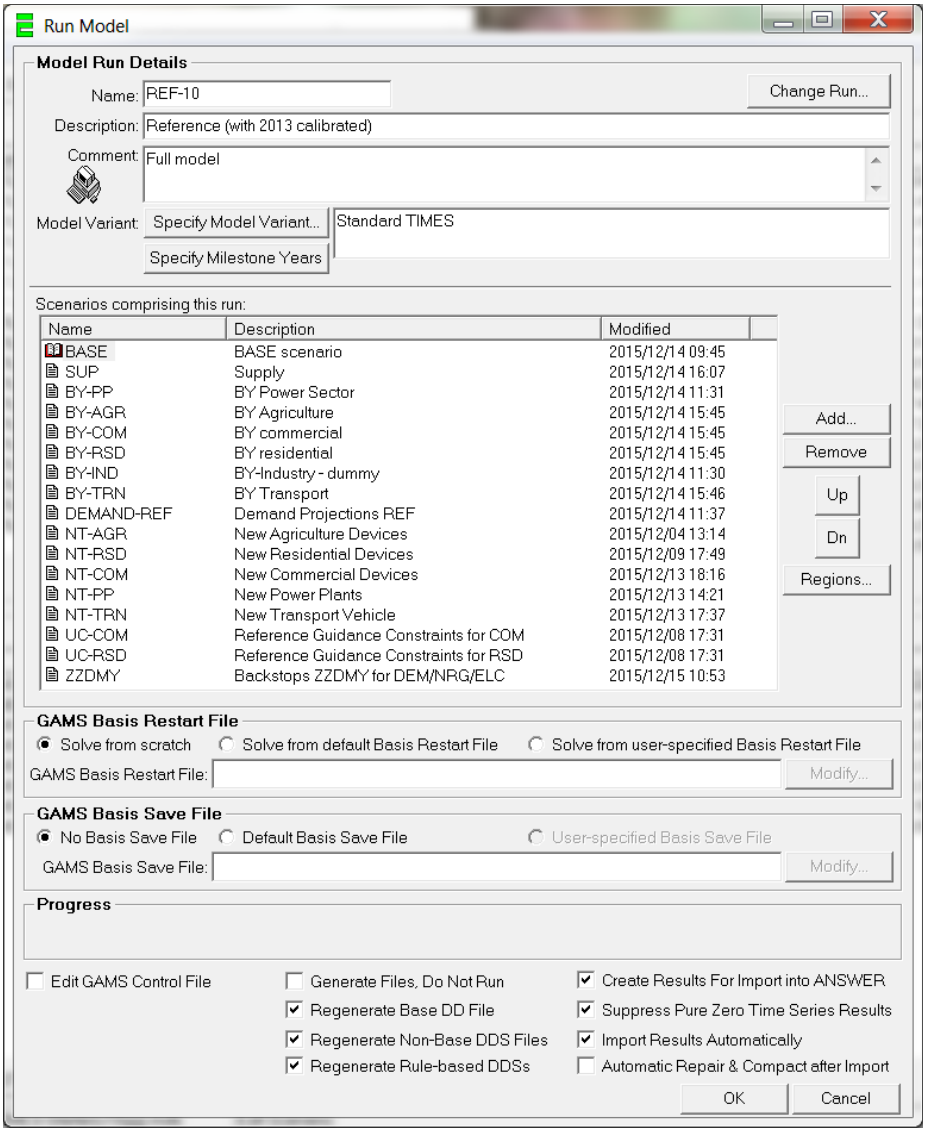

Note that as the model evolves if may be desirable to have fewer individual scenarios. To this end, combining all the BY-<sector> base scenarios into BY-REF and all the NT-<sector> into a single NT-TCH may be worth considering. Having said this, one advantage of keeping the sectors in their own templates is to facilitate team model development where several individuals are building the model so that changes can be made along sector lines and introduced selectively as appropriate.

## 7.4 Submitting a Model Run

With the templates imported into ANSWER they may be assembled into model runs by providing the list of scenarios to be included in a run, as shown in Figure 45 for the current Reference scenario. When assembling the scenario list it is important to keep in mind that:

- The order of the scenarios is important, as GAMS processes them in the order presented;
- Thus the TIMES code only "sees" the last value submitted, and any repeated parameter values (e.g., bounds) will overwrite the earlier values;
- For the Starter model it is important to have the Supply scenario appear before any of the sector scenarios, since the supply commodities (SUP<root><nrg>) are declared in it, and
- In general, the Run check box switches active below will work just fine.

**Figure 45: ANSWER Run Submission**




Once the OK button is hit:

- the model data will be assembled by ANSWER in the GAMS run folder;
- a Windows Command Prompt window will open and the model run undertaken, and
- the TIMES results are “dumped” for ANSWER (if requested) are imported (if Import Results Automatically selected).

As the run finishes up TIMES will also produce the results files needed for VBE, see Section 0.

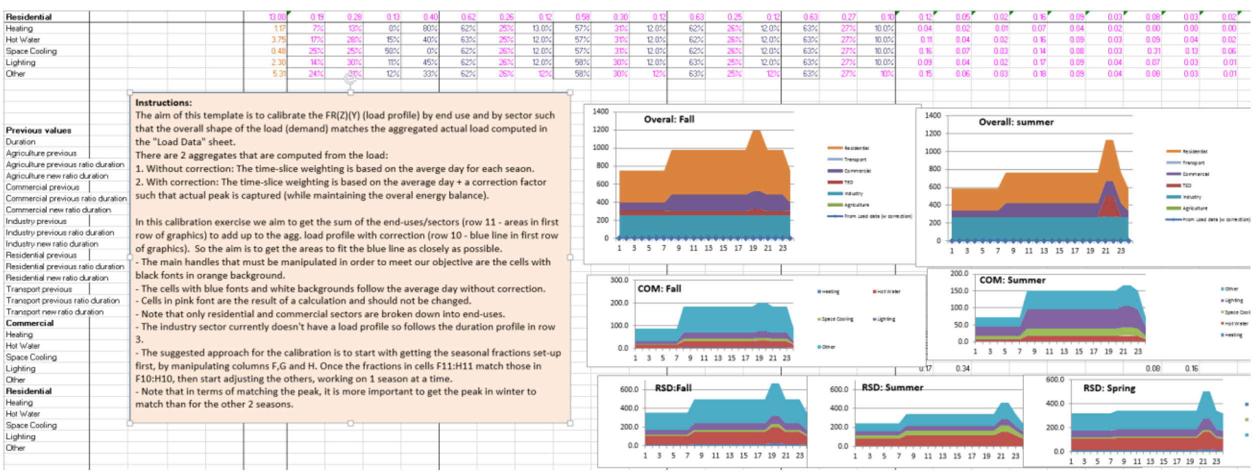
# 8 Adjusting the Load Duration Curve

An important aspect of defining the electric sector is creating the annual timeslices for the model that match the base year load duration curve. The TIMES-Starter is setup with twelve divisions of the year corresponding to four seasons (summer, fall, winter and spring) and three times of the day (day, night and peak) that apportion the load curve adequately for long-term planning purposes. While the user is free to change the number of divisions this needs to be done carefully and is not described here. We suggest that only very experienced modelers attempt to do so without expert guidance.

The number of months and hours of the day corresponding to each timeslice are defined on the Load data tab of the Loadcalibration workbook by entering the start and end day for each season. Based on the load duration curve, which consists of 8760 hourly electricity load values the base year (or most recent year available), the user must iterate on the load fractions for each timeslice and sector to get a reasonable approximation of the associated aggregate load curve that will be used by the model.

The timeslice information generated in the LoadCalibration workbook consists of the year breakdown (G_YRFRs) and the demand timing fractions (COM_FRs). This timeslice information is linked to the EB_Starter workbook, and then cascades into each of the sector workbooks. The timeslice information – particularly the period definitions, need to be taken into consideration when assigning the demand timing fractions for each end-use service with timing requirements (e.g., heating, cooling, lighting in particular).

**Figure 46: Load Calibration Worksheet**



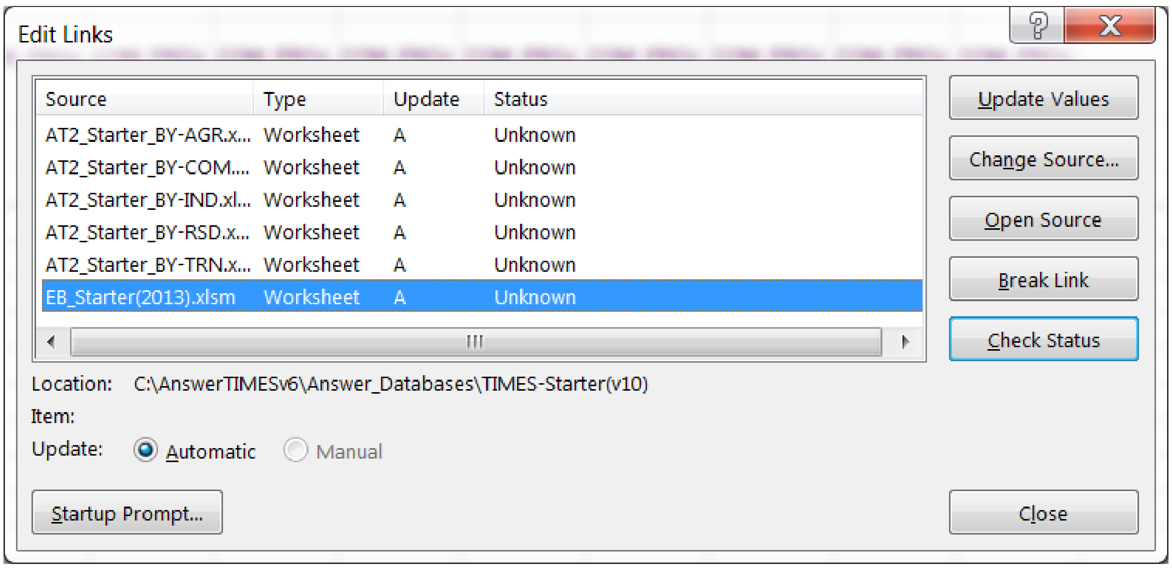

# 9 Forecasting Demands

A TIMES model solves to meet the projected future demand for energy services for each and every end-use service. Thus the demand projection is perhaps the first most important aspect of establishing a TIMES model. The Demand template has four (4) types of worksheets, each of which are discussed in this section.

- Base year calibration data;
- Demand drivers;
- Demand projection for each sector, and
- The ANSWER-TIMES loadsheets with the commodities (end-use service demand definitions) and projection (end-use service levels).

While there are various sophistications in terms of approaches to forecasting the energy service demands, including linking to macro-economic models[13], a rather straightforward yet reasonable and transparent approach is employed for the TIMES-Starter. The demand projections are seeded by the initial period energy service demand, as determined by the calibration process. Figure 47 shows that these BY values are coming from the BY templates, and Figure 48 shows the current levels as collected on the base year calibration data tab. The <sect> Demand tabs use the various demand drivers and sector-based elasticities to project future energy demands for each of the model demands as shown in Figure 49.

**Figure 47: Demand Template Dependencies**




For the Industry subsectors, two approaches are available. One uses subsector-based production growth indices, as shown in Figure 49, and the other uses elasticities to GDP, such as shown in the Residential demand example in Figure 50.

[13] Workshop on linking TIMES with economic model can be found at http://www.iea-etsap.org/web/UCC_Workshop14.asp and http://www.iea-etsap.org/web/Copenhagen_Nov2014.asp and summarized in '*Economic Impacts of Future Changes in the Energy System—Global Perspectives* chapter in **Springer Book** 'Informing energy and climate policies using energy systems models' 2015.

## Figure 48: BY Calibration Demand Levels

| | | | |
|---|---|---|---|
| Start year | | 2013 | |
| | Base Year Data per Sector | | |
| | **Agriculture sector** | | |
| | | | |
| | **BASE YEAR DATA (from BY templates)** | | PJ |
| | AWP | Agriculture Water Pumping | 0.04 |
| | ATH | Agriculture Tractors | 0.07 |
| * | ATF | Agriculture Tractors - Farm Op. | - |
| | AOE | Agriculture Other Use | - |
| | | | |
| | | **Commercial sector** | |
| | | | |
| | **BASE YEAR DATA (from BY templates)** | | PJ |
| | CSH | Commercial Heating | 6.98 |
| | CSC | Commercial Cooling | 2.79 |
| | CWH | Commercial Water Heating | 0.93 |
| * | CVT | Commercial Ventilation | - |
| | CCK | Commercial Cooking | 0.64 |
| | CLT | Commercial Lighting | 0.46 |
| | CRF | Commercial Refrigeration | 0.98 |
| * | COF | Commercial Office Equipment | - |
| | | | |
| | | **Residential sector** | |
| | | | |
| | **BASE YEAR DATA** | | PJ |
| | RHH | Residential Heating | 46.26 |
| | RHC | Residential Cooling | 8.38 |
| | RHW | Residential Water Heating | 4.26 |
| | RHR | Residential Refrigeration | 0.54 |
| * | RHK | Residential Freezing | - |
| | RHL | Residential Lighting | 2.17 |
| | RHO | Residential Other Appliances | 1.30 |

| | | | | |
|---|---|---|---|---|
| | | **Transport sector** | | |
| | **BASE YEAR DATA** | | | |
| * Light Duty | | | | |
| | TLD | Transport: Light Duty Vehicles | 5.61 | Bv-km |
| * Heavy Duty | | | | |
| | TAI | Transport: Air | 0.02 | bn-pass-km |
| | TBU | Transport: Bus | 0.22 | Bv-km |
| | TMD | Transport: Medium Duty Trucks | 0.34 | Bv-km |
| | THS | Transport: HDV Short Haul | 0.26 | Bv-km |
| | THL | Transport: HDV Long Haul | 0.11 | Bv-km |
| | TSH | Transport: Ship | 0.17 | bn-t-km |
| | TRF | Transport: Rail - Freight | 0.86 | bn-t-km |
| | TRP | Transport: Rail - Passanger | 1.65 | bn-pass-km |
| | TCT | Transport: Commercial Truck | 0.82 | Bv-km |
| * Off Road | | | | |
| | TOH | Transport: Off-road | - | Bv-km |
| | | | | |
| | | **Industrial sector** | | |
| | **BASE YEAR DATA (from BY templates)** | | PJ | |
| | ICHT | Chemical High Temperature | 0.21 | |
| | ICLT | Chemical Low Temperature | - | |
| | ICMD | Chemical Mechanical | 0.93 | |
| | IFHT | Food High Temperature | 1.92 | |
| | IFLT | Food Low Temperature | - | |
| | IFMD | Food Mechanical | 0.92 | |
| | IIHT | Iron Steel High Temperature | 1.46 | |
| | IILT | Iron Steel Low Temperature | - | |
| | IIMD | Iron Steel Mechanical | 2.31 | |
| | IMHT | Non-metallic High Temperature | 10.37 | |
| | IMLT | Non-metallic Low Temperature | - | |
| | IMMD | Non-metallic Mechanical | 0.38 | |
| | IOHT | Other High Temperature | 0.95 | |
| | IOLT | Other Low Temperature | - | |
| | IOMD | Other Mechanical | 0.71 | |

## Figure 49: Demand Drivers

| | | | Demand Drivers | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 2013 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
| **Driver** | | | | | | | | | | |
| GDP | unit | 6,187 | 6,589 | 8,017 | 10,232 | 13,059 | 16,667 | 21,271 | 27,148 | 34,649 |
| Population | 1000 persons | 4400 | 4400 | 4511 | 4625 | 4742 | 4862 | 4984 | 5110 | 5239 |
| Number of persons per household | | 3.80 | 3.76 | 3.67 | 3.58 | 3.49 | 3.40 | 3.32 | 3.24 | 3.16 |
| | | | | | | | | | | |
| GDP growth | | | 3.20% | 4.00% | 5.00% | 5.00% | 5.00% | 5.00% | 5.00% | 5.00% |
| Population growth | | | 0.00% | 0.50% | 0.50% | 0.50% | 0.50% | 0.50% | 0.50% | 0.50% |
| GDP/pop | | | 3.20% | 3.48% | 4.48% | 4.48% | 4.48% | 4.48% | 4.48% | 4.48% |
| Number of persons per household | | | -0.50% | -0.50% | -0.50% | -0.50% | -0.50% | -0.50% | -0.50% | -0.50% |
| Non-energy gas consumption | | | 30.00% | 4.00% | 5.00% | 5.00% | 5.00% | 5.00% | 5.00% | 5.00% |
| Degree days base year | 2553 | | | | | | | | | |
| Degree days average | 2584 | 1.012 | | | | | | | | |
| | | | | | | | | | | |
| **Number of years after first period** | 2 | | | | | | | | | |
| **Number of years per period after second period** | 5 | | | | | | | | | |
| | | | | | | | | | | |
| ***production index growth*** | | | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
| Chemical industry | | | 3.20% | 4.00% | 5.00% | 5.00% | 5.00% | 5.00% | 5.00% | 5.00% |
| Food, Beverages and Tobaco industry | | | 3.20% | 4.00% | 5.00% | 5.00% | 5.00% | 5.00% | 5.00% | 5.00% |
| Iron and steel industry | | | 3.20% | 4.00% | 5.00% | 5.00% | 5.00% | 5.00% | 5.00% | 5.00% |
| Non-metallic minerals industry | | | 3.20% | 4.00% | 5.00% | 5.00% | 5.00% | 5.00% | 5.00% | 5.00% |
| Other manufacturing industry | | | 3.20% | 4.00% | 5.00% | 5.00% | 5.00% | 5.00% | 5.00% | 5.00% |
| Construction | | | 3.20% | 4.00% | 5.00% | 5.00% | 5.00% | 5.00% | 5.00% | 5.00% |
| Non-ferrous metals industry | | | 3.20% | 4.00% | 5.00% | 5.00% | 5.00% | 5.00% | 5.00% | 5.00% |
| | | | | | | | | | | |
| | | 100 | 103.20 | 107.33 | 112.69 | 118.33 | 124.25 | 130.46 | 136.98 | 143.83 |

In addition to the demand drivers and elasticities, there are other factors that shape the demand projections, such as the number of persons per household, dependency of the service to the driver(s), saturation rate for the service, and so on. See the instructions on each of the sheets in the workbook.

Once all the components of the projection are assembled they are applied to prepare the forecast for each end-use, where the Residential sector is shown Figure 50.

**Figure 50: Residential Demand Forecast**

| Number of dwellings | 2013 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|---|
| Population | 4400 | 4400 | 4511 | 4625 | 4742 | 4862 | 4984 | 5110 | 5239 |
| Number of persons per household | 3.80 | 3.76 | 3.67 | 3.58 | 3.49 | 3.40 | 3.32 | 3.24 | 3.16 |
| Total number of households | 1158 | 1170 | 1230 | 1293 | 1359 | 1429 | 1502 | 1579 | 1660 |
| | | | | | | | | | |
| destruction rate per year (destrate) | 0.2% | | | | | | | | |
| **old dwellings** | 1158 | 1153 | 1142 | 1130 | 1119 | 1108 | 1097 | 1086 | 1075 |
| **new dwellings** | | 16 | 88 | 162 | 240 | 321 | 405 | 493 | 584 |
| **TOTAL** | 1158 | 1170 | 1230 | 1293 | 1359 | 1429 | 1502 | 1579 | 1660 |
| **SPACE HEATING** | | | | | | | | | |
| **Correction for degree days of total heat d** | 46.82 | | | | | | | | |
| **heat demand new/old (neffgain)** | 1.0 | | | | | | | | |
| **AEI factor for old (deffgain) (per year)** | 0.01 | | | | | | | | |
| | **2013** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** | **2045** | **2050** |
| **Elasticity for evolution with GDP/POP** | | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| | | | | | | | | | |
| **Heating demand per old dwelling** | 0.0404 | 0.0404 | 0.0405 | 0.0412 | 0.0419 | 0.0426 | 0.0434 | 0.0441 | 0.0449 |
| **Heating demand per new dwelling** | | 0.0404 | 0.0404 | 0.0405 | 0.0412 | 0.0419 | 0.0426 | 0.0434 | 0.0441 |
| | | | | | | | | | |
| **Heating demand total old dwellings** | 46.8207 | 46.5963 | 46.2356 | 46.5662 | 46.8992 | 47.2345 | 47.5722 | 47.9124 | 48.2550 |
| **Heating demand total new dwellings** | | 0.6588 | 3.5452 | 6.5664 | 9.8737 | 13.4311 | 17.2560 | 21.3672 | 25.7846 |
| **Total Heating Demand (PJ)** | 46.82 | 47.26 | 49.78 | 53.13 | 56.77 | 60.67 | 64.83 | 69.28 | 74.04 |
| **HOT WATER HEATING** | | | | | | | | | |
| | **2013** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** | **2045** | **2050** |
| **Elasticity for evolution with GDP/pop** | | 1.0 | 1.0 | 1.0 | 0.8 | 0.6 | 0.4 | 0.2 | 0.1 |
| Hot water demand per dwelling and per p | 0.0010 | 0.0010 | 0.0012 | 0.0015 | 0.0018 | 0.0021 | 0.0023 | 0.0024 | 0.0024 |
| **Total Hot Water Demand (PJ)** | 4.26 | 4.54 | 5.53 | 7.05 | 8.62 | 10.09 | 11.31 | 12.12 | 12.71 |
| **SPACE COOLING** | | | | | | | | | |
| **Cooling demand per dwelling** | **2013** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** | **2045** | **2050** |
| Apartments - Urban | | 4.00% | 4.00% | 4.00% | 4.00% | 4.00% | 4.00% | 4.00% | 4.00% |
| **Share of dwellings with cooling** | 30.00% | 34.00% | 38.00% | 42.00% | 46.00% | 50.00% | 54.00% | 58.00% | 62.00% |
| **Elasticity for evolution with GDP/POP** | | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |
| **Cooling demand per dwelling** | 0.0241 | 0.0247 | 0.0265 | 0.0290 | 0.0317 | 0.0346 | 0.0378 | 0.0413 | 0.0452 |
| **Total Cooling Demand (PJ)** | 8.38 | 9.84 | 12.39 | 15.73 | 19.79 | 24.72 | 30.67 | 37.84 | 46.47 |

# 10 Reference Scenario Guidance

The Reference (or sometimes called business-as-usual (BAU)) scenario strives to describe the evolution of the energy system following current practices and trends, while also reflecting all policies on the books that might influence that process. This scenario then serves as the point of departure for using TIMES to conduct an assessment of alternate futures in response to technology developments and policy interventions. But as discussed in the rest of this section there is a bit of an art to designing a viable Reference scenario that remains flexible enough to respond to these altered futures that are to be evaluated to assist with advising the formulation of such policies and measures.

## 10.1 The Need to Guide the Reference Scenario

A TIMES model makes all choices based upon a strict least-cost optimization. In principle, the better one depicts *all* relevant costs in the model, the better a Reference scenario can represent a BAU evolution of the energy system. However, there are many costs, both "hard" monetary costs and "soft" transaction, information, and consumer preference costs, that are difficult to value and enter into the model, but which cause real-world economic choices to differ from the choices an unguided TIMES model would make. Some of these costs are identified here.

- Infrastructure costs: There may be limitations on the ability to deliver some fuels to some sectors/businesses/dwellings, for example, owing to limited distribution infrastructure. In principle, where data exists for these costs, they should be represented in the model and included in its calculations. However, estimating these costs can be a very geographically specific process, and so good data may not be available. An alternative approach may be to limit the penetration of the relevant commodity within each sector/demand according to the status of infrastructure availability, potentially including a projection of availability increase over time..
- Hardware conversion costs: Even where fuels are available, there may be costs associated with converting an individual plant/dwelling from one fuel to another. Again, in principle it would be desirable to include these costs in the model, but in practice they are very difficult to estimate, and often consumers have inertia in that they prefer to stay with what they know rather than move to something else.
- Information and transaction costs/limitations: New or advanced devices may not be as widely available as standard devices, or individual sector decision-makers may be unfamiliar with them and unaware of their life-cycle cost effectiveness, or they may simply prefer to stick with devices they are familiar with.
- Financing costs/ limitations: Although individual sector decision-makers may prefer a new/advanced device due to its lower life-cycle costs, they may not be able to finance the upfront capital cost.
- Split incentives: In the residential or commercial sectors, when capital costs are paid by building owners and fuel costs are paid by renters, mismatched incentives may prevent higher capital cost, higher efficiency devices and conservation measures (such as insulating) from being selected.
- Other consumer preferences: Consumers may value attributes of a more expensive fuel or device beyond its direct costs and efficiency. Examples include the range of consumer preferences for light duty vehicles (LDV) of different sizes, which must be imposed on the model to prevent it from meeting the entire LDV demand with compact cars, and preferences for more convenient and cleaner liquid and gaseous fuels over solid fuels for space heating.

In order to represent these costs, or the impacts of these costs, on real world choices, a variety of mechanisms are used to guide the Reference scenario to better reflect likely BAU outcomes.

## 10.2 Types of Guidance Mechanisms

To handle each of the challenges mentioned in the previous section a variety of available mechanisms and how they have been implemented in the TIMES-Starter Model are discussed in the next subsections. The sections that follow also discuss considerations that must be thought through in determining whether and how to adjust these mechanisms in policy scenario runs.

### 10.2.1 Forced operation of existing devices

Uncontrolled, the model may choose to abandon (stop using) existing power plants and demand devices before the end of their technical life, if they are sufficiently inefficient relative to new devices that the model finds it cheaper to replace them. While this may be efficient from a system perspective, in a BAU world, individuals rarely toss out an appliance or scrap a car before it "dies" and capital may be unavailable to prematurely replace existing devices. To represent this limitation, the existing devices may be forced to continue to operate at a specified fraction of their potential output but setting a gradually fading away lower bound.

In the TIMES-Starter model, this mechanism has been illustrated in the BOUNDLO scenario, which forces operation of existing power plants over the initial model periods at a declining percentage of their base year operation levels. Figure 51 shows a screenshot of the ProcData sheet of the BOUNDLO scenario template. As a starting point, it provides a lower bound on activity (ACT_BND-LO) for all existing electricity, CHP, and district heating plants in two model periods, 2015 and 2025, with interpolation between them. The lower bound for each process is calculated as the product of its base year electricity or heat production, as entered in the Calibration worksheet in the PP-BY template, and the desired minimum level of operation relative to that base year operation, as specified in the orange cells. Different control cells for ELE, CHP, and HPLs have been provided, and in 2025, ELEs have been further differentiated by fuel type, so that the user may easily release bounds on some processes in policy scenarios that might benefit from the option to reduce utilization of some units, for example, in a renewable portfolio standard (RPS) scenario. An example of such a reduction is provided in the BOUNDLO-RED (for reduced) scenario, which has been included in place of BOUNDLO in several of the example policy scenarios in the Starter database.

The user may wish to customize this scenario by setting different forced operation levels for different plants, or by extending the time horizon of forced operation (taking care that no devices are forced to operate beyond their technical LIFE, which will lead to an infeasibility.)

**Figure 51: BOUNDLO Scenario Template**

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | ProcData | STARTER | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | Check Sheet | ProcName, ProcDesc, Units | | | CommIN | CommOUT | | | | |
| 4 | Parameter | | | | * | | | ACT_BND-LO | ACT_BND-LO | ACT_BND-LO |
| 5 | Qualifier1 | | | | | | | ANNUAL | ANNUAL | ANNUAL |
| 6 | Qualifier2 | | | | | | | | | |
| 7 | | ProcName | ProcDesc | ProcUnits | CommIN | CommOUT | Activity I/O | 2015 | 2025 | 0 |
| 8 | | EERNWHYD-DM-X0 | Hydro (Dam) (Existing) | PJ,GW | PWRRNWHY | ELCT | | 1.425 | 0.975 | 1 |
| 9 | | EERNWHYD-RR-X0 | Hydro (Run-of-River) (Existing) | PJ,GW | PWRRNWHY | ELCT | | 0.475 | 0.325 | 1 |
| 10 | * | EERNWHYD-PS-X0 | Hydro (Pumped Storage) (Existing) | PJ,GW | PWRRNWHY | ELCT | | 0 | 0 | 1 |
| 11 | | EEGASNAT-CC-X0 | Natural Gas - Combined cycle (Existing) | PJ,GW | PWRGASNA | ELCT | | 2.85 | 1.95 | 1 |
| 12 | | EEGASNAT-CT-X0 | Natural Gas - Combustion turbine (Existing) | PJ,GW | PWRGASNA | ELCT | | 3.18744 | 1.308528 | 1 |
| 13 | | EECOAOBC-ST-X0 | Bituminous (Brown Coal) - Steam turbine (Ex | PJ,GW | PWRCOAOE | ELCT | | 1.425 | 0.585 | 1 |
| 14 | | EECOASBC-ST-X0 | Sub-Bituminous Coal - Steam turbine (Existin | PJ,GW | PWRCOASB | ELCT | | 1.425 | 0.585 | 1 |
| 15 | | EECOALIG-ST-X0 | Lignite - Steam turbine (Existing) | PJ,GW | PWRCOALIC | ELCT | | 1.425 | 0.975 | 1 |
| 16 | | EECOALIG-IG-X0 | Lignite - Integrated Gasif. (Existing) Combinec | PJ,GW | PWRCOALIC | ELCT | | 0.95 | 0.65 | 1 |
| 17 | | EENUCLER-LWR-X0 | Nuclear - LWR (Existing) | PJ,GW | PWRNUCLEI | ELCT | | 10.45295155 | 7.152019481 | 1 |
| 18 | | EEBIOGAS-EN-X0 | Biogases - Engine (Existing) | PJ,GW | PWRBIOGAS | ELCT | | 0.475 | 0.195 | 1 |
| 19 | | EEBIOGAS-GT-X0 | Biogases - Gas turbine (Existing) | PJ,GW | PWRBIOGAS | ELCT | | 0.475 | 0.195 | 1 |
| 20 | | EEBIOGAS-ST-X0 | Biogases - Steam turbine (Existing) | PJ,GW | PWRBIOGAS | ELCT | | 0.2375 | 0.0975 | 1 |
| 21 | | EEBIOGAS-CC-X0 | Biogases - Combined cycle (Existing) | PJ,GW | PWRBIOGAS | ELCT | | 0.2375 | 0.0975 | 1 |
| 22 | | EEBIOMSW-ST-X0 | Municipal Waste - Steam turbine (Existing) | PJ,GW | PWRBIOMSV | ELCT | | 0.95 | 0.65 | 1 |
| 23 | | EEBIOPSF-IG-X0 | Primary Solid Biofuels - Integrated Gasif. Com | PJ,GW | PWRBIOPSF | ELCT | | 0.646 | 0.442 | 1 |
| 24 | | EERNWGEO-ST-X0 | Geothermal - Steam turbine (Existing) | PJ,GW | PWRRNWGE | ELCT | | 0.475 | 0.325 | 1 |
| 25 | | EERNWSOL-TC-X0 | Solar - Thermal Central (Existing) | PJ,GW | PWRRNWSC | ELCT | | 0.95 | 0.65 | 1 |
| 26 | | EERNWWIN-ON-X0 | Wind - Onshore (Existing) | | PWRRNWWI | ELCT | | 0.95 | 0.65 | 1 |
| 27 | | EERNWWIN-OF-X0 | Wind - Offshore (Existing) | | PWRRNWWI | ELCT | | 0.475 | 0.325 | 1 |
| 28 | | EHBIOPSF-ST-X0 | Coupled Heat & Power Primary Solid Biofuels - Steam turk | | PWRBIOPSF | ELCT | | 0.730769231 | 0.5 | 1 |
| 29 | | | | | | LTHC | | | | |
| 30 | | EHCOAANT-ST-X0 | Coupled Heat & Power Anthracite (Hard Coal) - Steam tur | | PWRCOAAN | ELCT | | 1.235 | 0.845 | 1 |
| 31 | | | | | | LTHC | | | | |
| 32 | | EHGASNAT-CC-X0 | Coupled Heat & Power Natural Gas - Combined cycle (Exi | | PWRGASNA | ELCT | | 1.357142857 | 0.928571429 | 1 |
| 33 | | | | | | LTHC | | | | |
| 34 | | EHGASNAT-EN-X0 | Coupled Heat & Power Natural Gas - Engine (Existing) | | PWRGASNA | ELCT | | 0.863636364 | 0.590909091 | 1 |
| 35 | | | | | | LTHC | | | | |
| 36 | * | EHOILFOI-ST-X0 | Coupled Heat & Power Fuel Oil - (Existing) | | PWROILFOI | ELCT | | 0 | 0 | 1 |
| 37 | * | | | | | LTHC | | | | |

| | K | L | M | N | O | P | Q | R | S | T | U | V | W |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | * | * | * | * | * | * | * | * | * | * | * | * |
| 4 | | 2015 MIN % | ELE | CHP | HPL | | 2025 MIN % | ELE-COAL | ELE-GAS | ELE-RE | ELE-NUC | CHP | HPL |
| 5 | | | 95% | 95% | 95% | | | 65% | 65% | 65% | 65% | 65% | 65% |

Evelyn:
Enter desired minimum operation levels, relative to base year operation.

### 10.2.2 Market share constraints

Market share constraints can be imposed to provide "friction" in the model, slowing it from switching between devices or groups of devices used to produce a given commodity or commodities, or meet a demand. For example, they may be used to maintain the share of heating demand met by a particular fuel or kind of device (e.g., stove vs furnace), or to slow the penetration of a class of improved devices, such as LED light bulbs.

Devices can be forced to a minimum or maximum share of the consumption or production of a specified commodity (including energy service demands) using the FLO_MARK parameter for an individual device or the UCRULE_MARK user constraint to restrict a class or group of devices. To impose a market share constraint on a group of technologies, the TIMES user constraint capability is used along with ANSWER Named Filters. In order to group existing and new technologies together, and retain flexibility for the user to add multiple devices in each demand/fuel/type set, the user constraint mechanism has been used in the TIMES-Starter model instead of the FLO_MARK parameter. Section 10.3 provides a closer look at how these market share user constraints have been implemented in the TIMES-Starter model.

### 10.2.3 Hurdle rates

Although the model contains an overall global discount rate (G_DRATE) used to discount all costs to a base year, technology-specific discount rates may be set (using NCAP_DRATE) to represent financing costs applicable to a particular device or sector. (For example, power plants may face financing costs in the range of 10-15 percent, while residential purchases may face higher financing costs reflecting the use of credit cards or consumer loans for purchases.) This parameter may also be used to represent some of the soft costs described above that impede the penetration of more efficient devices. In this usage, the parameter is called a "hurdle" rate, as it represents additional impediments that a device must overcome in order to be attractive to consumers. For example, households may behave as if they face financing costs of 50 percent or higher, or they require very short payback periods in order to choose a more efficient device with a higher upfront cost.

While a technically sound approach to modeling these soft costs, hurdle rates can be challenging to use in practice because the appropriate values are difficult to estimate, and they introduce an artificial cost into the objective function that can make scenario cost comparisons difficult. So in TIMES what is usually done is apply hurdle rates to improved devices that slow their penetration in the Reference scenario to an acceptable level, which may mean keeping them out altogether. Then when doing policy scenarios that are aimed at lowering the barriers to the uptake of such technologies, the hurdle rates can be lowered and their penetration evaluated. To help with this task the TIMES report writer splits out the core investment expenditures (using the global discount rate) and the amount arising due to the higher discount rate. This helps give a sense of the potential costs and benefits of policies that have the potential to lower these hurdle rates.

*{Although the templates contain entries for NCAP_DRATE (from USEPA), they are commented out for demand devices at this time (though are used for some heating plants (HPLs). A mechanism will be introduced where hurdle rates may be used in place to UC_<sect> new technology market penetration limiting constraints.}*

### 10.2.4 BOUNDS and GROWTH rates on new technology uptake

It may be the case that for some technologies there are real-world impediments to them quickly being adapted and deployed. Examples might be that the necessary skills to put up wind turbines or the number of electric car charging stations are limited, or it may be difficult to gain consumer acceptance or financing for the first examples of new technology adoption. To handle such situations one may specify a direct bound on such a technology or use the TIMES dynamic bound user constraint facility that limits the penetration of a new technology based upon a specified percent increase over what is already deployed.

An example of the former has been provided in the TECH-BOUND scenario, which places an upper capacity bound (CAP_BND-UP) on the CHP technology EHGASNAT-CC, which proved to be very attractive in policy runs using the default Starter model configuration. The bound starts at 50 MW in 2015, the year of the device's first availability, and ramps up to 500 MW, or approximately 15% of total model capacity, by the end of the horizon. The user should review this bound to see if it is appropriate for their model, as well as assess whether there are other technologies that should receive a bound to directly slow their penetration rate.

## 10.3 A Closer Look at Market Share User Constraints in the TIMES-Starter Model

Market share constraints enable various aspects of the evolution of the energy system to be guided while not imposing explicit bounds on individual technologies options. The mechanism can be easily implemented in an ANSWER-TIMES model by use of the UC_MARK parameter, when a single commodity (demand) is involved. To identify the group of technologies that are to be subjected to a market share constraint, an ANSWER Named Filter is used.

The following categories of Named Filters have been created in the TIMES-Starter model, where the lead character is used as part of naming the filters and the corresponding market share constraints.

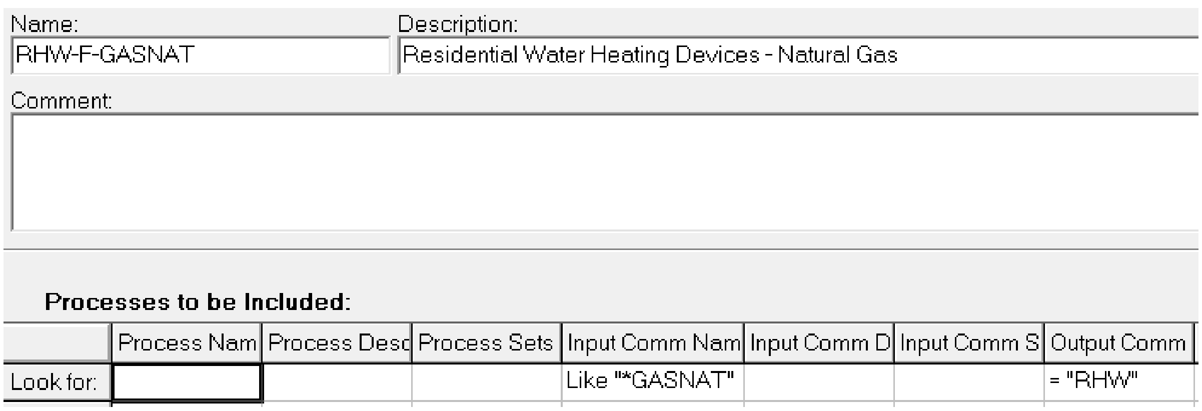
- **F**uel: used to group devices by demand served and fuel consumed, for example, natural gas residential space heaters, or electric commercial cooking devices. Constraints built using these filters represent inhibitions on consumers switching fuels used to meet demands, due to infrastructure or hardware limitations, or familiarity and preferences.
- **T**ype: used to group devices of any previously defined type. Constraints built using these filters may be used to slow penetration of a class of advanced devices, such as hybrid vehicles, or may represent limitations on the applicability of one type of device to meeting only a portion of a given demand, such as walk-in freezers, or rooftop commercial air conditioners. As described in Section 5.4, these types have been incorporated into demand device names by means of strict naming conventions in each SETUP sheet, in order to facilitate their use in building Named Filters.
- **Q**uality: used to group devices of a similar designated level of energy efficiency. Options include: standard, improved, best, and advanced. (Note: "advanced" devices have higher efficiencies than those named "best".) As with types, these quality levels have been built into device names to facilitate their grouping into Named Filter sets. Example constraints using these filters have

been constructed to illustrate how to use them to slow penetration of high-efficiency devices across whole sectors and individual demands.

- **S**ize: used only for size classes of light-duty vehicles, such as compact, full-size, minivan, etc. These vehicle classes have inherently different efficiencies due to their weight and configuration, and it is necessary for the user to specify the evolution of consumer preferences for these size classes.

These filters are built manually in ANSWER, using the Named Filters facility shown in Figure 52 for the natural gas devices meeting the Residential Water Heating demand. The resulting TIMES user-defined constraint equation can be previewed by going to the Constraints tab, highlighting the constraint of interest, and requesting via the right-mouse Resolve Rule-based Constraint, with the resulting equation components displayed along the lines shown in Figure 53.

**Figure 52: ANSWER Named Filter Specification Form**



Name: RHW-F-GASNAT

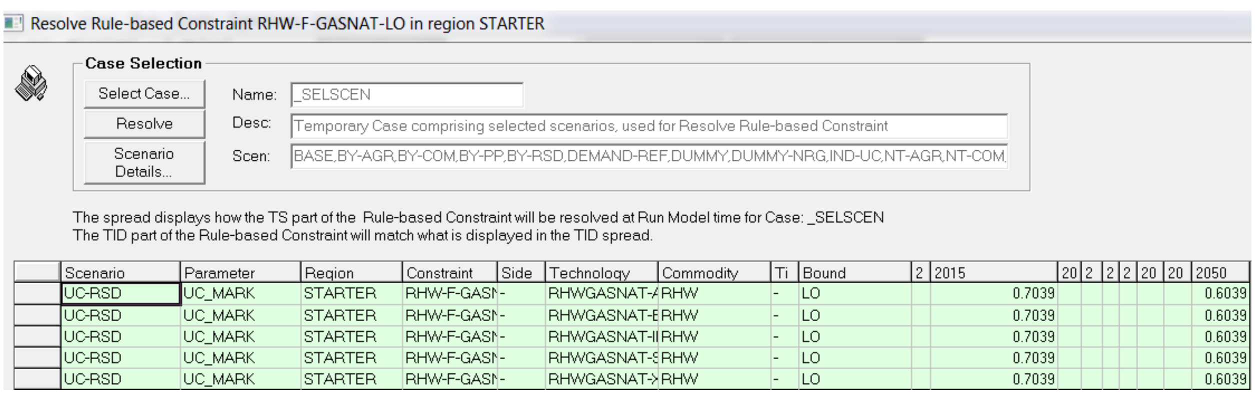
Description: Residential Water Heating Devices - Natural Gas

Comment:

**Processes to be Included:**

| | Process Nam | Process Desc | Process Sets | Input Comm Nam | Input Comm D | Input Comm S | Output Comm |
|---|---|---|---|---|---|---|---|
| Look for: | | | | Like "*GASNAT" | | | = "RHW" |

**Figure 53: ANSWER Resolve User Constraint Display**



Resolve Rule-based Constraint RHW-F-GASNAT-LO in region STARTER

Case Selection

Select Case...
Resolve
Scenario Details...

Name: _SELSCEN

Desc: Temporary Case comprising selected scenarios, used for Resolve Rule-based Constraint

Scen: BASE,BY-AGR,BY-COM,BY-PP,BY-RSD,DEMAND-REF,DUMMY,DUMMY-NRG,IND-UC,NT-AGR,NT-COM,

The spread displays how the TS part of the Rule-based Constraint will be resolved at Run Model time for Case: _SELSCEN
The TID part of the Rule-based Constraint will match what is displayed in the TID spread.

| Scenario | Parameter | Region | Constraint | Side | Technology | Commodity | Ti | Bound | 2 | 2015 | 20 | 2 | 2 | 2 | 20 | 20 | 2050 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UC-RSD | UC_MARK | STARTER | RHW-F-GASN | - | RHWGASNAT-A | RHW | - | LO | | 0.7039 | | | | | | | 0.6039 |
| UC-RSD | UC_MARK | STARTER | RHW-F-GASN | - | RHWGASNAT-E | RHW | - | LO | | 0.7039 | | | | | | | 0.6039 |
| UC-RSD | UC_MARK | STARTER | RHW-F-GASN | - | RHWGASNAT-II | RHW | - | LO | | 0.7039 | | | | | | | 0.6039 |
| UC-RSD | UC_MARK | STARTER | RHW-F-GASN | - | RHWGASNAT-S | RHW | - | LO | | 0.7039 | | | | | | | 0.6039 |
| UC-RSD | UC_MARK | STARTER | RHW-F-GASN | - | RHWGASNAT-X | RHW | - | LO | | 0.7039 | | | | | | | 0.6039 |

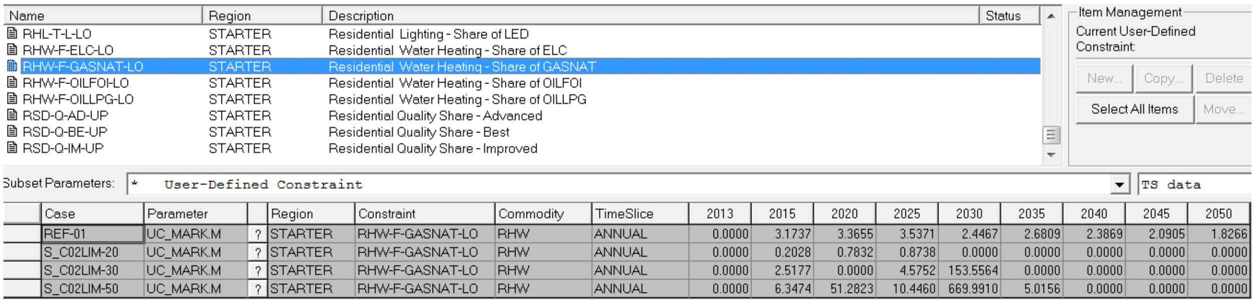
To complete the naming of the user constraints built in TIMES to control the market shares the sector, fuel, and sense are incorporated, as seen below for the list of current Residential share constraints, where RH = Residential Heating, H = Households, F = Fuel type constraint, GASNAT = the fuel, and LO = sense of the equation.

**Figure 54: Residential Market Share Constraints**

| | | |
|---|---|---|
| RHC-F-ELC-LO | STARTER | Residential Cooling - Share of ELC |
| RHC-F-GASNAT-UP | STARTER | Residential Cooling - Share of GASNAT |
| RHC-T-C-LO | STARTER | Residential Cooling - Share of Central |
| RHC-T-R-LO | STARTER | Residential Cooling - Share of Room |
| RHH-F-BIOPSF-UP | STARTER | Residential Heating - Share of BIOPSF |
| RHH-F-ELC-LO | STARTER | Residential Heating - Share of ELC |
| RHH-F-GASNAT-LO | STARTER | Residential Heating - Share of GASNAT |
| RHH-F-OILFOI-LO | STARTER | Residential Heating - Share of OILFOI |
| RHH-F-OILKER-LO | STARTER | Residential Heating - Share of OILKER |
| RHH-F-OILLPG-LO | STARTER | Residential Heating - Share of OILLPG |
| RHH-Q-AD-UP | STARTER | Residential Heating Quality Share - Advanced |
| RHH-Q-BE-UP | STARTER | Residential Heating Quality Share - Best |
| RHH-Q-IM-UP | STARTER | Residential Heating Quality Share - Improved |
| RHH-T-F-LO | STARTER | Residential Heating - Share of Furnace |
| RHH-T-H-LO | STARTER | Residential Heating - Share of Heat Pump |
| RHH-T-R-LO | STARTER | Residential Heating - Share of Radiant |
| RHH-T-S-LO | STARTER | Residential Heating - Share of Stove |
| RHL-T-C-LO | STARTER | Residential Lighting - Share of CFL |
| RHL-T-F-LO | STARTER | Residential Lighting - Share of Fluorescent |
| RHL-T-H-LO | STARTER | Residential Lighting - Share of Halogen |
| RHL-T-I-LO | STARTER | Residential Lighting - Share of Incandescent |
| RHL-T-L-LO | STARTER | Residential Lighting - Share of LED |
| RHW-F-ELC-LO | STARTER | Residential Water Heating - Share of ELC |
| RHW-F-GASNAT-LO | STARTER | Residential Water Heating - Share of GASNAT |
| RHW-F-OILFOI-LO | STARTER | Residential Water Heating - Share of OILFOI |
| RHW-F-OILLPG-LO | STARTER | Residential Water Heating - Share of OILLPG |
| RSD-Q-AD-UP | STARTER | Residential Quality Share - Advanced |
| RSD-Q-BE-UP | STARTER | Residential Quality Share - Best |
| RSD-Q-IM-UP | STARTER | Residential Quality Share - Improved |

Another important consideration when setting up the market share mechanism is the sense of the constraint, that is whether it imposes an Upper or Lower limit on the fuel or technology group. Upper limits need to be applied when something is excessively attractive to the model and lower limits used when it is not attractive, but some minimum level must be met, which may differ for the TIMES-Starter and your model. The way to ascertain this is to look at whether the constraints are binding (hitting their limit) or not by looking at the UC_MARK.M parameter in ANSWER or the Marginal Prices (User Constraint) table in VBE. For the Residential natural gas for water heating constraint above, notice that there is a lower bound applied as gas is not the least-cost choice for water heating in the Starter model and so it must be forced in, which can be seen in the ANSWER snapshot of constraint marginals shown in Figure 55. Where there are no marginals, the limit has not been reached, indicating that perhaps the sense of the equation needs to be reversed. This trial and redo process needs to be completed for all the market share constraints as part of readying the Reference scenario.

## Figure 55: Market Share Constraint Marginals

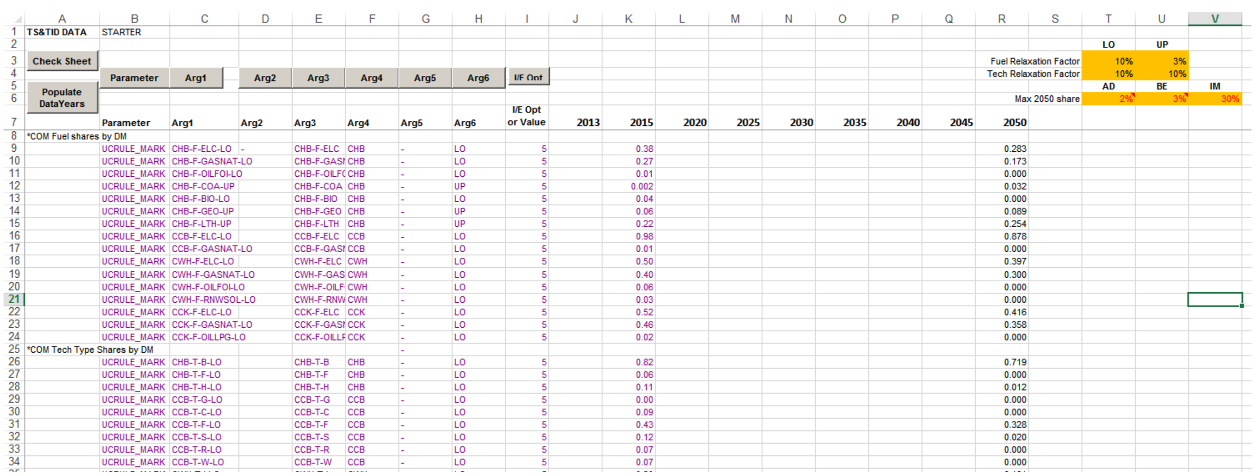



| Name | Region | Description | Status |
|---|---|---|---|
| RHL-T-L-LO | STARTER | Residential Lighting - Share of LED | |
| RHW-F-ELC-LO | STARTER | Residential Water Heating - Share of ELC | |
| RHW-F-GASNAT-LO | STARTER | Residential Water Heating - Share of GASNAT | |
| RHW-F-OILFOI-LO | STARTER | Residential Water Heating - Share of OILFOI | |
| RHW-F-OILLPG-LO | STARTER | Residential Water Heating - Share of OILLPG | |
| RSD-Q-AD-UP | STARTER | Residential Quality Share - Advanced | |
| RSD-Q-BE-UP | STARTER | Residential Quality Share - Best | |
| RSD-Q-IM-UP | STARTER | Residential Quality Share - Improved | |

| Case | Parameter | | Region | Constraint | Commodity | TimeSlice | 2013 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| REF-01 | UC_MARK.M | ? | STARTER | RHW-F-GASNAT-LO | RHW | ANNUAL | 0.0000 | 3.1737 | 3.3655 | 3.5371 | 2.4467 | 2.6809 | 2.3869 | 2.0905 | 1.8266 |
| S_C02LIM-20 | UC_MARK.M | ? | STARTER | RHW-F-GASNAT-LO | RHW | ANNUAL | 0.0000 | 0.2028 | 0.7832 | 0.8738 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| S_C02LIM-30 | UC_MARK.M | ? | STARTER | RHW-F-GASNAT-LO | RHW | ANNUAL | 0.0000 | 2.5177 | 0.0000 | 4.5752 | 153.5564 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| S_C02LIM-50 | UC_MARK.M | ? | STARTER | RHW-F-GASNAT-LO | RHW | ANNUAL | 0.0000 | 6.3474 | 51.2823 | 10.4460 | 669.9910 | 5.0156 | 0.0000 | 0.0000 | 0.0000 |

The user constraints have been constructed in AT version 1 workbooks, one for each of the COM, RSD, and TRN sectors, providing a starting point for users to adjust to their own study area. Figure 56 shows a screenshot of the fuel and technology type constraints in the UC-COM template. The 2015 share values are linked to the useful energy shares by technology group calculated on the Calibration sheet of each BY sector workbook, as discussed in Section 5.4.2.1. The 2050 values are loosened from the starting values by means of the orange-shaded control cells in the upper right corner. These cells specify the fraction of the demand that is free to move into/out of the relevant fuel/type by 2050. Note that because we tend to use the UPper bound on fuels that are less desirable (like coal and biomass) or have limits on availability and/or infrastructure (like district heat), the default relaxation value for the UPper fuel UCs has been set lower than for the LOwers.

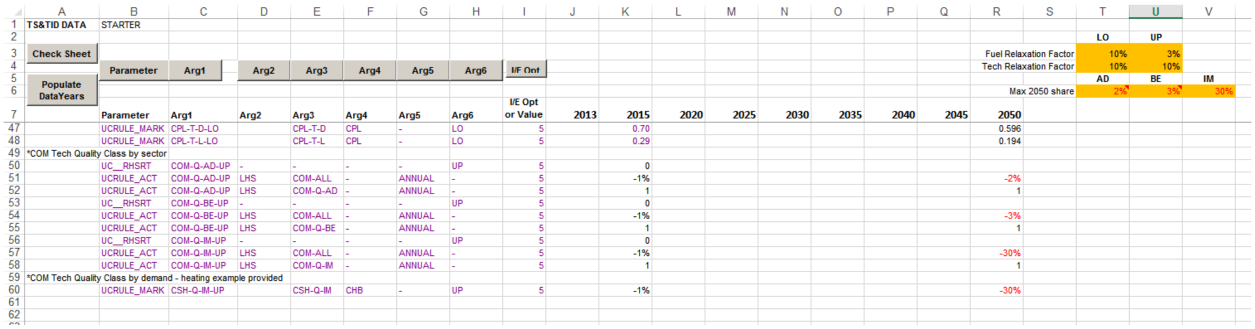
## Figure 56: UC-COM Template




| Row | A | Parameter | Arg1 | Arg2 | Arg3 | Arg4 | Arg5 | Arg6 | I/E Opt or Value | 2013 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | *COM Fuel shares by DM | | | | | | | | | | | | | | | | | |
| 9 | | UCRULE_MARK | CHB-F-ELC-LO | - | CHB-F-ELC | CHB | - | LO | 5 | | 0.38 | | | | | | | 0.283 |
| 10 | | UCRULE_MARK | CHB-F-GASNAT-LO | | CHB-F-GASI | CHB | - | LO | 5 | | 0.27 | | | | | | | 0.173 |
| 11 | | UCRULE_MARK | CHB-F-OILFOI-LO | | CHB-F-OILF( | CHB | - | LO | 5 | | 0.01 | | | | | | | 0.000 |
| 12 | | UCRULE_MARK | CHB-F-COA-UP | | CHB-F-COA | CHB | - | UP | 5 | | 0.002 | | | | | | | 0.032 |
| 13 | | UCRULE_MARK | CHB-F-BIO-LO | | CHB-F-BIO | CHB | - | LO | 5 | | 0.04 | | | | | | | 0.000 |
| 14 | | UCRULE_MARK | CHB-F-GEO-UP | | CHB-F-GEO | CHB | - | UP | 5 | | 0.06 | | | | | | | 0.089 |
| 15 | | UCRULE_MARK | CHB-F-LTH-UP | | CHB-F-LTH | CHB | - | UP | 5 | | 0.22 | | | | | | | 0.254 |
| 16 | | UCRULE_MARK | CCB-F-ELC-LO | | CCB-F-ELC | CCB | - | LO | 5 | | 0.98 | | | | | | | 0.878 |
| 17 | | UCRULE_MARK | CCB-F-GASNAT-LO | | CCB-F-GASI | CCB | - | LO | 5 | | 0.01 | | | | | | | 0.000 |
| 18 | | UCRULE_MARK | CWH-F-ELC-LO | | CWH-F-ELC | CWH | - | LO | 5 | | 0.50 | | | | | | | 0.397 |
| 19 | | UCRULE_MARK | CWH-F-GASNAT-LO | | CWH-F-GAS | CWH | - | LO | 5 | | 0.40 | | | | | | | 0.300 |
| 20 | | UCRULE_MARK | CWH-F-OILFOI-LO | | CWH-F-OILF | CWH | - | LO | 5 | | 0.06 | | | | | | | 0.000 |
| 21 | | UCRULE_MARK | CWH-F-RNWSOL-LO | | CWH-F-RNW | CWH | - | LO | 5 | | 0.03 | | | | | | | 0.000 |
| 22 | | UCRULE_MARK | CCK-F-ELC-LO | | CCK-F-ELC | CCK | - | LO | 5 | | 0.52 | | | | | | | 0.416 |
| 23 | | UCRULE_MARK | CCK-F-GASNAT-LO | | CCK-F-GASI | CCK | - | LO | 5 | | 0.46 | | | | | | | 0.358 |
| 24 | | UCRULE_MARK | CCK-F-OILLPG-LO | | CCK-F-OILLF | CCK | - | LO | 5 | | 0.02 | | | | | | | 0.000 |
| 25 | *COM Tech Type Shares by DM | | | | | | - | | | | | | | | | | | |
| 26 | | UCRULE_MARK | CHB-T-B-LO | | CHB-T-B | CHB | - | LO | 5 | | 0.82 | | | | | | | 0.719 |
| 27 | | UCRULE_MARK | CHB-T-F-LO | | CHB-T-F | CHB | - | LO | 5 | | 0.06 | | | | | | | 0.000 |
| 28 | | UCRULE_MARK | CHB-T-H-LO | | CHB-T-H | CHB | - | LO | 5 | | 0.11 | | | | | | | 0.012 |
| 29 | | UCRULE_MARK | CCB-T-G-LO | | CCB-T-G | CCB | - | LO | 5 | | 0.00 | | | | | | | 0.000 |
| 30 | | UCRULE_MARK | CCB-T-C-LO | | CCB-T-C | CCB | - | LO | 5 | | 0.09 | | | | | | | 0.000 |
| 31 | | UCRULE_MARK | CCB-T-F-LO | | CCB-T-F | CCB | - | LO | 5 | | 0.43 | | | | | | | 0.328 |
| 32 | | UCRULE_MARK | CCB-T-S-LO | | CCB-T-S | CCB | - | LO | 5 | | 0.12 | | | | | | | 0.020 |
| 33 | | UCRULE_MARK | CCB-T-R-LO | | CCB-T-R | CCB | - | LO | 5 | | 0.07 | | | | | | | 0.000 |
| 34 | | UCRULE_MARK | CCB-T-W-LO | | CCB-T-W | CCB | - | LO | 5 | | 0.07 | | | | | | | 0.000 |

Below the fuel and type constraints on this sheet are sample device quality constraints, one for each of ADvanced, BEst, and IMproved devices, as shown in Figure 57. Examples have been provided for the entire commercial sector and for the commercial space heating demand. The 2050 maximum penetration for each quality level is specified in the bottom row of orange control cells.

Figure 57: Device Quality Constraints in the UC-COM Template



| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | TS&TID DATA | STARTER | | | | | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | | | | LO | UP | |
| 3 | Check Sheet | | | | | | | | | | | | | | | | | Fuel Relaxation Factor | | 10% | 3% | |
| 4 | | Parameter | Arg1 | Arg2 | Arg3 | Arg4 | Arg5 | Arg6 | I/E Opt | | | | | | | | | Tech Relaxation Factor | | 10% | 10% | |
| 5 | Populate DataYears | | | | | | | | | | | | | | | | | | | AD | BE | IM |
| 6 | | | | | | | | | | | | | | | | | | Max 2050 share | | 2% | 3% | 30% |
| 7 | | Parameter | Arg1 | Arg2 | Arg3 | Arg4 | Arg5 | Arg6 | I/E Opt or Value | 2013 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 | | | | |
| 47 | | UCRULE_MARK | CPL-T-D-LO | | CPL-T-D | CPL | - | LO | 5 | | 0.70 | | | | | | | 0.596 | | | | |
| 48 | | UCRULE_MARK | CPL-T-L-LO | | CPL-T-L | CPL | - | LO | 5 | | 0.29 | | | | | | | 0.194 | | | | |
| 49 | *COM Tech Quality Class by sector | | | | | | | | | | | | | | | | | | | | | |
| 50 | | UC__RHSRT | COM-Q-AD-UP | - | - | - | - | UP | 5 | | 0 | | | | | | | | | | | |
| 51 | | UCRULE_ACT | COM-Q-AD-UP | LHS | COM-ALL | - | ANNUAL | - | 5 | | -1% | | | | | | | -2% | | | | |
| 52 | | UCRULE_ACT | COM-Q-AD-UP | LHS | COM-Q-AD | - | ANNUAL | - | 5 | | 1 | | | | | | | 1 | | | | |
| 53 | | UC__RHSRT | COM-Q-BE-UP | - | - | - | - | UP | 5 | | 0 | | | | | | | | | | | |
| 54 | | UCRULE_ACT | COM-Q-BE-UP | LHS | COM-ALL | - | ANNUAL | - | 5 | | -1% | | | | | | | -3% | | | | |
| 55 | | UCRULE_ACT | COM-Q-BE-UP | LHS | COM-Q-BE | - | ANNUAL | - | 5 | | 1 | | | | | | | 1 | | | | |
| 56 | | UC__RHSRT | COM-Q-IM-UP | - | - | - | - | UP | 5 | | 0 | | | | | | | | | | | |
| 57 | | UCRULE_ACT | COM-Q-IM-UP | LHS | COM-ALL | - | ANNUAL | - | 5 | | -1% | | | | | | | -30% | | | | |
| 58 | | UCRULE_ACT | COM-Q-IM-UP | LHS | COM-Q-IM | - | ANNUAL | - | 5 | | 1 | | | | | | | 1 | | | | |
| 59 | *COM Tech Quality Class by demand - heating example provided | | | | | | | | | | | | | | | | | | | | | |
| 60 | | UCRULE_MARK | CSH-Q-IM-UP | | CSH-Q-IM | CHB | - | UP | 5 | | -1% | | | | | | | -30% | | | | |
| 61 | | | | | | | | | | | | | | | | | | | | | | |
| 62 | | | | | | | | | | | | | | | | | | | | | | |

Because many policy goals may entail encouraging increased uptake of more efficient devices, the user may wish to release these quality constraints somewhat in policy scenarios. UC-50 and 90 versions of the UC workbooks, with correspondingly higher 2050 UPper bounds for these quality constraints have been provided. This issue is discussed further in the next section.

## 10.4 Considerations for Policy Analysis

All of the mechanisms described above, when properly applied, will serve to slow down change in the energy system away from its present configuration to one that uses different fuels and higher efficiency devices. When analyzing a policy that is designed to shift the evolution of the energy system, such as a carbon policy or an energy efficiency standard, care must be taken to determine whether and how any of these mechanisms should be loosened and how to interpret the results.

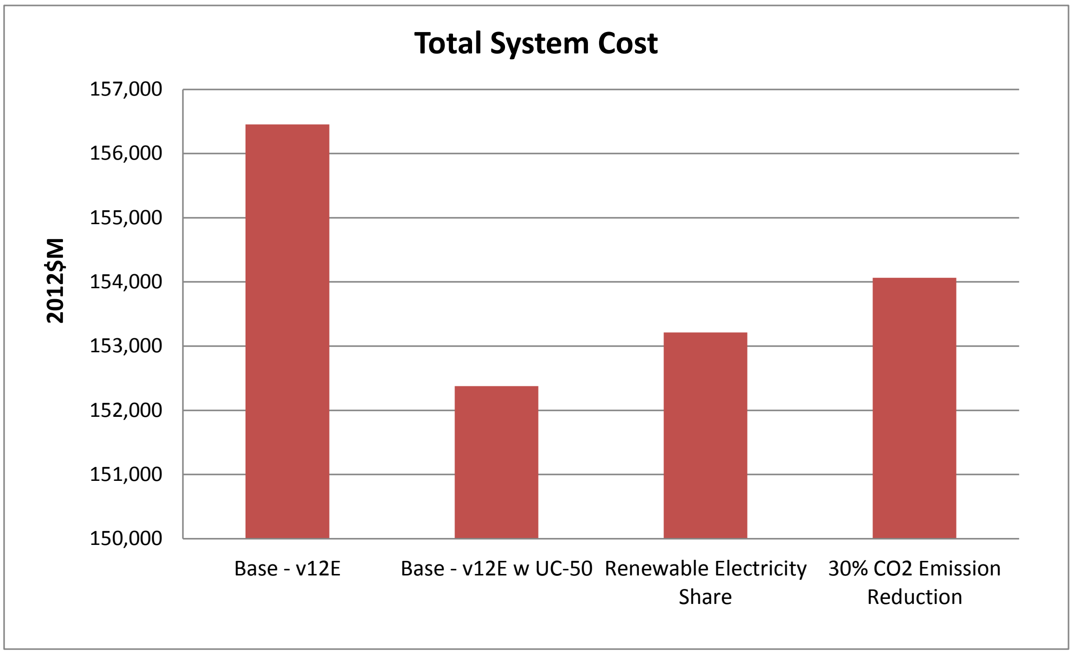
For example, a policy to promote energy efficiency will likely include measures that aim to reduce the “soft” costs described in Section 10.1. It may provide information to individual sector decision-makers about high efficiency options, offer subsidized financing, provide energy audits that identify least cost choices for consumers, or subsidize conversion costs. To evaluate the impact of these measures the user will need to loosen the mechanisms designed to represent these costs. Therefore, one way to model such a policy is to run the model with loosened guidance mechanisms and identify where the largest cost and energy savings occur. Keep in mind that when any of these mechanisms are loosened (that is, a lower bound is reduced or eliminated, an upper bound is increased or eliminated, or hurdle rates are lowered), the system cost will be reduced relative to the previously constrained scenario because the model has more freedom to make lower cost choices. In the case of this analysis, the total savings from loosening these mechanisms can be compared to the estimated costs of the policies and measures in order to determine their cost effectiveness. Alternatively, individual measures targeted at particular sectors or subsectors can be assessed by loosening only the relevant constraints/mechanisms (such as a residential energy efficiency policy that reduces hurdle rates or loosens constraints on the penetration of advanced devices.)

On the other hand, if a policy designed to induce change in the system – such a carbon constraint or price, or a standard that limits total final/primary energy or energy intensity – is implemented without loosening the Reference guidance mechanisms, the model may have little room to respond to the policy and/or the policy may be quite expensive. This approach simulates, for example, the imposition of a carbon tax without any complementary measures designed to reduce transactions and other soft costs. In this case, the user may wish to compare four scenarios:

- The Reference scenario;
- A scenario with guidance mechanisms loosened, but no other policies imposed, to represent energy efficiency promotion measures;
- The policy scenario, keeping Reference level guidance mechanisms in place, and
- The policy scenario with loosening of guidance mechanisms, to represent the policy plus complementary measures.

Figure 58 provides an example, where the Base and Base with UC-50 represents the savings inherent with reducing the soft costs discussed above, and the costs increases of the RPS and CO2 scenarios, which use UC-50 represent the additional costs of the policies after implementation of the implied soft cost measures.

**Figure 58: System cost example with and without relaxed guidance mechanisms**




In all cases, what is necessary is to be clear about what is being modeled in each scenario and to check if each type and instance of guidance mechanism is appropriate or not to the policy under consideration, as discussed in the next section.

# 11 Alternate Scenarios Basics

Alternate scenarios are usually designed to test the impact of possible changes from the Reference scenario arising from policy, supply, price or technology interventions that may alter the evolution of the energy system. Therefore, these scenarios, with a leading prefix S_, are usually based upon imposing explicit changes from Reference scenario values. These can take the form of:

- A forced change in the absolute value of a Reference scenario result, e.g. decrease in final energy consumption of 25% by a target year;
- A forced change in the share of a Reference scenario result, e.g., a target share of 50% renewable electricity generation by a target year, and
- The introduction of a cost or tax on the system, e.g., imposing a price on carbon emissions.

In the case of those scenarios that are based upon setting a target derived from a Reference scenario level, these scenarios must be seeded with the appropriate Reference scenario values, which may be done via Copy/Paste from the appropriate VBE table, and then the desired policy described and imported into ANSWER as a separate scenario that can be then be included in model runs independently of or in combination with other such scenario variants. This ability to directly impose a policy goal or other alternative view of the future and have TIMES reconfigure the resulting energy system to find the new least-cost evolution of the energy system adhering to this new development is one of the key differences between an optimization framework such as TIMES and a simulation or accounting framework (such as LEAP[14]).

As mentioned in the previous section, under most policy situations the user will want to replace the Reference scenario UCs and other Reference guidance mechanisms that restrict the rate at which fuel switching and new technology uptake can take place with looser versions that permit more fuel switching and more rapid uptake of new technologies.

## 11.1 Managing ANSWER Scenarios

The Starter model includes a set of example scenarios for some of the most common types of scenarios used.

- Target for renewable electricity generation (called RPS for Renewable Portfolio Standard);
- Forced reduction in $CO_2$ emissions by a fixed percent from the Reference scenario results;
- Forced reduction in final energy consumption by a fixed percent from the Reference scenario results
- Forced reduction in electricity consumption by a fixed percent from the Reference scenario results (setup directly in ANSWER);
- CO2 Tax, and
- GHG emissions limits;

Management of these scenarios fall into essentially two categories, those based on the Reference that require model results to be exported from VBE and simpler scenarios that can be easily setup directly in ANSWER. To facilitate the creation and reuse of such common policy scenarios the TIMES-Starter comes with a series of simple workbooks that contain a VBE table (updated via either Copy/Paste or UpdateXLS) to handle the former, and a couple of examples of the latter built directly in ANSWER, as discussed in the rest of this section. It is important when using these workbooks to make sure that the

[14] http://www.energycommunity.org/default.asp?action=47

Reference scenario and alternative scenario to be used/prepared and checked are BOTH selected as the Global Filter for the UpdateXLS operation.

The top-level result for  each policy scenarios is the total discounted system cost (or model objective function), and  a couple of explanations are necessary to understand change in the objective function results, shown in Figure 59.  Note first off that the REF-01-50/90 scenarios are less expensive than the REF-01 itself. This is due to allowing a faster uptake of efficient technologies, which is also the case in the other S_policy runs. So the best indicator of the incremental cost of each S_policy run can be seen by comparing them against the REF-01-50 scenario, since all the policy runs use that improvement assumption in terms of the rate of technology update. Furthermore, the policy scenarios also loosen the requirements to use some existing technologies that are imposed for the REF scenarios, which gives the model a bit more freedom to shape more rapid change in the energy system. And in the case of the S_RPS scenario a higher level of hydro, solar, geothermal and wind actually enables a more cost effective configuration of the energy system then was otherwise possible, despite the extra requirement to use more renewables for electricity generation.  Each of these findings is discussed in more detail under each scenario result.

**Figure 59: Policy Run Objective Function Values (Total Discounted System Cost)**

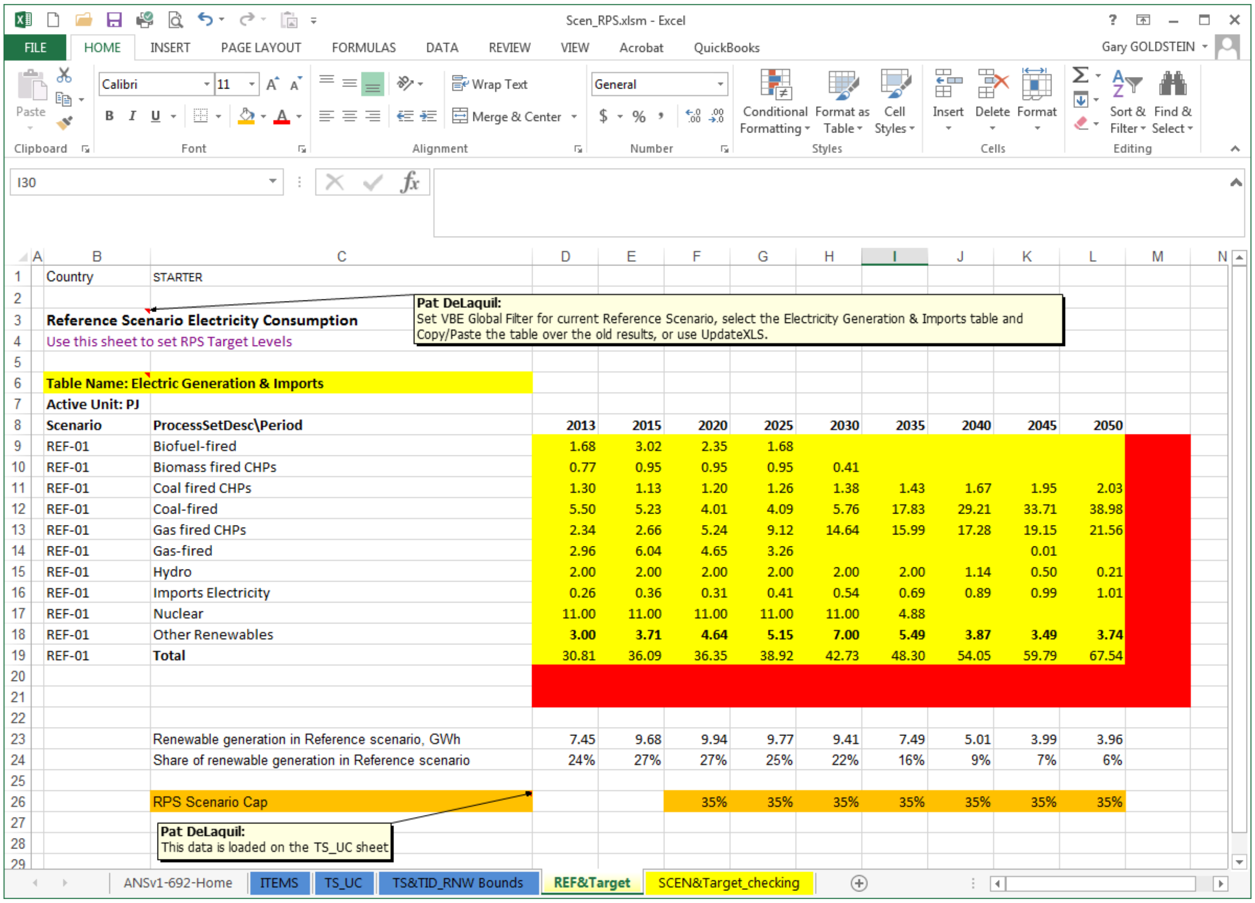
| Scenario | ObjZ |
|---|---|
| REF-01 | 150,184 |
| REF-01-50 | 146,119 |
| REF-01-90 | 144,471 |
| S_CO2LIM-20 | 146,647 |
| S_CO2LIM-30 | 150,831 |
| S_CO2LIM-40 | 151,466 |
| S_CO2LIM-50 | 153,200 |
| S_CO2TAX | 214,428 |
| S_GHGLIM-20 | 146,273 |
| S_LIMFEC | 150,252 |
| S_LIMFELC | 148,848 |
| S_RPS | 145,958 |

## 11.2 Renewable Electricity Portfolio Requirement (Scen_RPS)

This scenario template allows the user to set a target for a minimum percentage of electricity generation to be produced from renewable energy sources by creating a user constraint that forces electricity generated by all renewable power plants (including CHPs) to be at least the target level of total electricity generation.   The User Constraint is named P_RPS and is declared on the ITEMS sheet of this AT ver1 workbook.  The target levels are specified to the model via the TS_UC tab, but they are generated on the REF&Target tab, where the Reference scenario results are captured by copy-pasting the specified VBE table as shown in the screen shot below.  The VBE table shows total electricity generation & imports, and the calculations below the table provide the Reference scenario percentage of renewable energy generation to allow the target levels to be better determined.   These target levels are user-specified in the orange cells and may vary over time.

The proper operation of the scenario may be checked on the SCEN&Target_checking tab – by using the same VBE table for electricity generation, but copy-pasting the S_RPS scenario results into this checking sheet, where any variation can be seen.

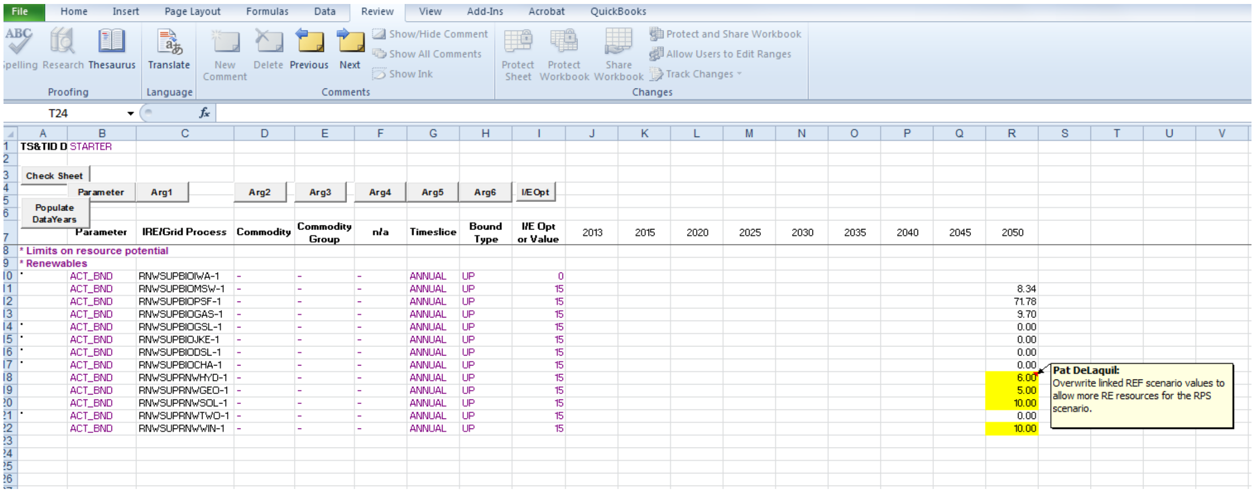
**Figure 60: Renewable Electricity Portfolio Requirement Specification Table**




| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Country | STARTER | | | | | | | | | |
| **Reference Scenario Electricity Consumption** | | | | | | | | | | |
| Use this sheet to set RPS Target Levels | | | | | | | | | | |
| **Table Name: Electric Generation & Imports** | | | | | | | | | | |
| **Active Unit: PJ** | | | | | | | | | | |
| **Scenario** | **ProcessSetDesc\Period** | **2013** | **2015** | **2020** | **2025** | **2030** | **2035** | **2040** | **2045** | **2050** |
| REF-01 | Biofuel-fired | 1.68 | 3.02 | 2.35 | 1.68 | | | | | |
| REF-01 | Biomass fired CHPs | 0.77 | 0.95 | 0.95 | 0.95 | 0.41 | | | | |
| REF-01 | Coal fired CHPs | 1.30 | 1.13 | 1.20 | 1.26 | 1.38 | 1.43 | 1.67 | 1.95 | 2.03 |
| REF-01 | Coal-fired | 5.50 | 5.23 | 4.01 | 4.09 | 5.76 | 17.83 | 29.21 | 33.71 | 38.98 |
| REF-01 | Gas fired CHPs | 2.34 | 2.66 | 5.24 | 9.12 | 14.64 | 15.99 | 17.28 | 19.15 | 21.56 |
| REF-01 | Gas-fired | 2.96 | 6.04 | 4.65 | 3.26 | | | | 0.01 | |
| REF-01 | Hydro | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 1.14 | 0.50 | 0.21 |
| REF-01 | Imports Electricity | 0.26 | 0.36 | 0.31 | 0.41 | 0.54 | 0.69 | 0.89 | 0.99 | 1.01 |
| REF-01 | Nuclear | 11.00 | 11.00 | 11.00 | 11.00 | 11.00 | 4.88 | | | |
| REF-01 | Other Renewables | **3.00** | **3.71** | **4.64** | **5.15** | **7.00** | **5.49** | **3.87** | **3.49** | **3.74** |
| REF-01 | **Total** | 30.81 | 36.09 | 36.35 | 38.92 | 42.73 | 48.30 | 54.05 | 59.79 | 67.54 |
| | Renewable generation in Reference scenario, GWh | 7.45 | 9.68 | 9.94 | 9.77 | 9.41 | 7.49 | 5.01 | 3.99 | 3.96 |
| | Share of renewable generation in Reference scenario | 24% | 27% | 27% | 25% | 22% | 16% | 9% | 7% | 6% |
| | RPS Scenario Cap | | | 35% | 35% | 35% | 35% | 35% | 35% | 35% |

When running such an RPS scenario, it may be the case that the Reference scenario assumptions with respect to renewable potential in particular may not permit attainment of higher level targets. To accommodate this, the scenario file allows for an additional set of input changes that permit easy adjustment of the renewable resource supply bounds. The TS&TID_RNW Bounds tab reflects the levels of renewable energy resource potential in the Reference scenario. However, a renewable energy target scenario implies greater incentives to develop renewable energy resources, and those upper bounds highlighted in yellow have values that were increased for this scenario, as shown below.

## Figure 61: Renewable Resource Potential Adjustment Table



TS&TID D STARTER

* Limits on resource potential
* Renewables

| Parameter | IRE/Grid Process | Commodity | Commodity Group | n/a | Timeslice | Bound Type | I/E Opt or Value | 2013 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ACT_BND | RNWSUPBIOIWA-1 | - | - | - | ANNUAL | UP | 0 | | | | | | | | | |
| ACT_BND | RNWSUPBIOMSW-1 | - | - | - | ANNUAL | UP | 15 | | | | | | | | | 8.34 |
| ACT_BND | RNWSUPBIOPSF-1 | - | - | - | ANNUAL | UP | 15 | | | | | | | | | 71.78 |
| ACT_BND | RNWSUPBIOGAS-1 | - | - | - | ANNUAL | UP | 15 | | | | | | | | | 9.70 |
| ACT_BND | RNWSUPBIOGSL-1 | - | - | - | ANNUAL | UP | 15 | | | | | | | | | 0.00 |
| ACT_BND | RNWSUPBIOJKE-1 | - | - | - | ANNUAL | UP | 15 | | | | | | | | | 0.00 |
| ACT_BND | RNWSUPBIODSL-1 | - | - | - | ANNUAL | UP | 15 | | | | | | | | | 0.00 |
| ACT_BND | RNWSUPBIOCHA-1 | - | - | - | ANNUAL | UP | 15 | | | | | | | | | 0.00 |
| ACT_BND | RNWSUPRNWHYD-1 | - | - | - | ANNUAL | UP | 15 | | | | | | | | | 6.00 |
| ACT_BND | RNWSUPRNWGEO-1 | - | - | - | ANNUAL | UP | 15 | | | | | | | | | 5.00 |
| ACT_BND | RNWSUPRNWSOL-1 | - | - | - | ANNUAL | UP | 15 | | | | | | | | | 10.00 |
| ACT_BND | RNWSUPRNWTWO-1 | - | - | - | ANNUAL | UP | 15 | | | | | | | | | 0.00 |
| ACT_BND | RNWSUPRNWWIN-1 | - | - | - | ANNUAL | UP | 15 | | | | | | | | | 10.00 |

**Pat DeLaquil:** Overwrite linked REF scenario values to allow more RE resources for the RPS scenario.

The S_RPS run specification in ANSWER includes the UC-50 and BOUNDLO-REDuced versions of the Reference guidance scenarios, as discussion in Section 10.

## 11.3 CO2 Targets (Scen_CO2-xx)

The Starter model includes four example scenarios that force reductions in $CO_2$ emissions by 20, 30, 40 and 50% below the Reference scenario levels. The structure of this template, shown in Figure 62, is similar to that used for the RPS scenario, with a REF&Target tab where the Reference scenario $CO_2$ levels are entered from the indicated VBE table and the target levels, which vary over time, are calculated based on the reduction percentages entered in the yellow highlight cells.

## Figure 62: $CO_2$ Emission Reduction Adjustment Table

Country: STARTER

**Reference Scenario CO2 Emissions**
Use this sheet to set CO2 Target Levels

Table Name: CO2 Emissions (by Sector)
Active Unit: kt

| Scenario | CommodityDesc\Period | 2013 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|---|---|
| REF-12E | Carbon dioxide - Agriculture | 32 | 24 | 25 | 26 | 28 | 30 | 33 | 36 | 40 |
| REF-12E | Carbon dioxide - Commercial | 178 | 181 | 193 | 218 | 232 | 251 | 274 | 302 | 333 |
| REF-12E | Carbon dioxide - Industry | 1266 | 1305 | 1433 | 1614 | 1817 | 2046 | 2303 | 2593 | 2920 |
| REF-12E | Carbon dioxide - Power Generation | 3274 | 3316 | 3718 | 5017 | 7081 | 10588 | 13920 | 15894 | 17988 |
| REF-12E | Carbon dioxide - Residential | 1601 | 1651 | 1747 | 1866 | 1939 | 2060 | 2258 | 2337 | 2377 |
| REF-12E | Carbon dioxide - Transport | 2526 | 2622 | 2894 | 3061 | 3232 | 3522 | 3981 | 4426 | 5003 |
| REF-12E | Total | 8877 | 9098 | 10010 | 11802 | 14329 | 18497 | 22770 | 25588 | 28660 |
| | Target, % below the Reference | 0 | 0 | 15% | 17.5% | 20.0% | 22.5% | 25.0% | 27.5% | 30% |
| | Target Emissions, Kt | 8877 | 9098 | 8509 | 9736 | 11463 | 14335 | 17078 | 18551 | 20062 |

**Pat DeLaquil:** Set VBE Global Filter for current Reference Scenario, select CO2 Emissions (by Sector) table and Copy/Paste the table over the old results.

**Anna:** This data is loaded on the CommData_target sheet

**Anna:** Insert CO2 reduction target in this row, by year

## 11.4 Final Energy Consumption Reduction (Scen_LIMFEC)

The final energy consumption reduction scenario is often used to examine policies to promote energy efficiency. The structure of this template is similar to that used for the RPS and $CO_2$ scenarios, with a

REF&Target tab, shown in Figure 63, where the Reference scenario FEC levels, by sector) are entered from the indicated VBE table and the target levels, which vary over time, are calculated based on the reduction percentages entered in the yellow highlight cells. The FEC reductions are currently do not include the IND sector, but that will be corrected once the IND sector is built out.

**Figure 63: FEC Reduction Scenario Adjustment Table**

Country | STARTER

**Reference Scenario Final Energy Consumption**

Use this sheet to set FEC Target Levels

**Pat DeLaquil:**
Set VBE Global Filter for current Reference Scenario, select Final Energy Consumption (by Sector) table and Copy/Paste the table over the old results.

**Table Name: Final Energy Consumption (by Sector)**

**Active Unit: PJ**

| Scenario | ProcessSetDesc\Period | 2013 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|---|---|
| REF-12E | Agriculture | 0.57 | 0.48 | 0.50 | 0.54 | 0.59 | 0.64 | 0.71 | 0.77 | 0.85 |
| REF-12E | Commercial | 9.35 | 9.57 | 10.44 | 11.74 | 13.21 | 14.40 | 15.45 | 16.55 | 18.21 |
| REF-12E | Industry | 33.17 | 34.18 | 37.55 | 42.28 | 47.60 | 53.59 | 60.34 | 67.94 | 76.49 |
| REF-12E | Residential | 67.38 | 66.84 | 66.84 | 68.20 | 69.81 | 72.76 | 77.40 | 80.19 | 80.44 |
| REF-12E | Transportation | 36.67 | 38.13 | 42.31 | 45.18 | 48.21 | 53.11 | 60.18 | 67.33 | 76.20 |
| REF-12E | Total | 147.15 | 149.20 | 157.65 | 167.94 | 179.41 | 194.50 | 214.07 | 232.77 | 252.19 |
| | Reduction target (%) | | | 5% | 10% | 15% | 15% | 15% | 15% | 15% |
| | Final Energy Consumption Cap | | 115 | 114 | 113 | 112 | 120 | 131 | 140 | 149 |

**Anna:**
Enter reduction target by year in this row

**Pat DeLaquil:**
This data is loaded on the TS_UC sheet

## 11.5 Reduction of Electricity Consumption (SCEN_LIMELC)

EE policies, such as described in the previous section, often result in an increase in electricity consumption since very often when forcing a reduction in total consumption TIMES may turn heavily to electric devices given their relative efficiency (which does not take into account the conversion losses at the point of generation). This scenario forces a reduction in electricity consumption as a counterbalance to this tendency. Its structure is similar to that used for the RPS and $CO_2$ scenario, with a REF&Target tab where the Reference scenario ELC consumption levels, by sector) are entered from the indicated VBE table and the target levels, which vary over time, are calculated based on the reduction percentages entered in the yellow highlight cells.

## 11.6 GHG Emission Reduction (SCEN_GHG)

The structure of this scenario is similar to the $CO_2$ reduction scenarios described in Section 11.3, but is applied to the basket of Greenhouse Gas (GHG) tracked in the model including $CO_2$, CH4 and N2O.

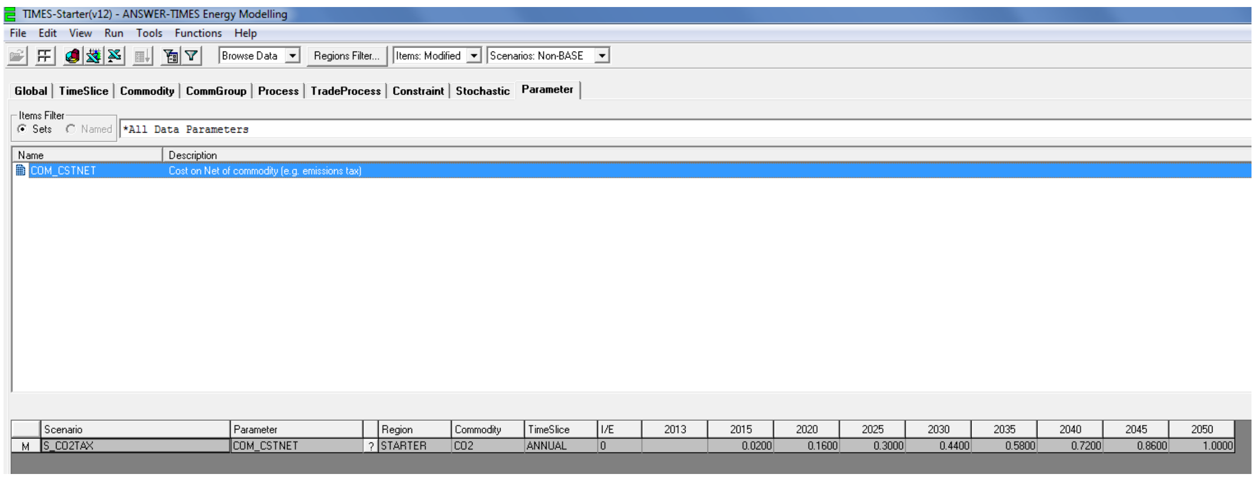
## 11.7 Simpler Scenario Handling Directly In ANSWER

Some scenarios are not dependent on Reference scenario results and/or require only a small amount of data to be introduced to the model, and can be handled most expeditiously directly in ANSWER, for example:

- Applying a price on $CO_2$. A scenario file was created for this example, but the figure below shows the ANSWER data which defines this scenario requires only one line of data to enter the price level;
- Imposing a cumulative $CO_2$ limit. This scenario can be defined by a single entry value, which specified the limit on cumulative $CO_2$ emissions (using the COM_CUMPRD parameter) so that TIMES determines the optimal timing to achieve the desired reduction level.
- Adjusting the price of oil (other energy resource), and
- Changing the cost of a technology (e.g., a nuclear power plant).

The snapshots below show an example the $CO_2$ price in the form of the ANSWER parameter specifications that enable it to be applied.

**Figure 64: Scenario Parameter Specification in ANSWER**




# 12 TIMES-Starter VBE Database

VEDA Back-End (VBE) is a simple to use, yet very powerful platform for managing and digging into TIMES model results. Refer to the “Using VEDA-BE with ANSWER-TIMES” manual for a fuller description of how to use VBE in conjunction with ANSWER. Here we discuss how VBE is configured to support the TIMES-Starter model.

VBE relies on solid naming conventions, like those employed for the Starter model, to ensure that the user-defined sets created for the Starter model capture all the components of the RES needed to build tables that organize the raw model results into common analysis tables, such as primary energy use, final energy use, electricity or gas production, emissions by sector, etc.. For example, the Starter VBE has sets that group fuels by their “root name” (all oil-based commodities or all forms of coal), or power plant types according to the fuels they use (all coal-fired plants), as discussed in Section 3, so that the basic energy system analysis tables included in the Starter VBE provide meaningful and digestible results that can be presented to non-modelers.

## 12.1 TIMES-Starter VBE Sets

The current list of Commodity Sets employed for the Starter model is shown in Figure 65. These include basic sets for energy, electricity and heat, sectoral demand and fuel-based energy sets. Note that the sets with black text are generated by TIMES, and the red-text sets were created for the Starter model which may be augmented by the user. Figure 66 shows a partial list of the Process sets employed for the Starter model, with the Commercial space heating process set selected. Process sets are often used to create subsets for energy use, capacity additions, investment requirements and emissions, and other parameters according to the fuel or plant/device type or demand sector. The list of process sets should be studied to understand what has already been created and to avoid making duplicate sets.

**Figure 65: TIMES-Starter VBE Commodity Sets**

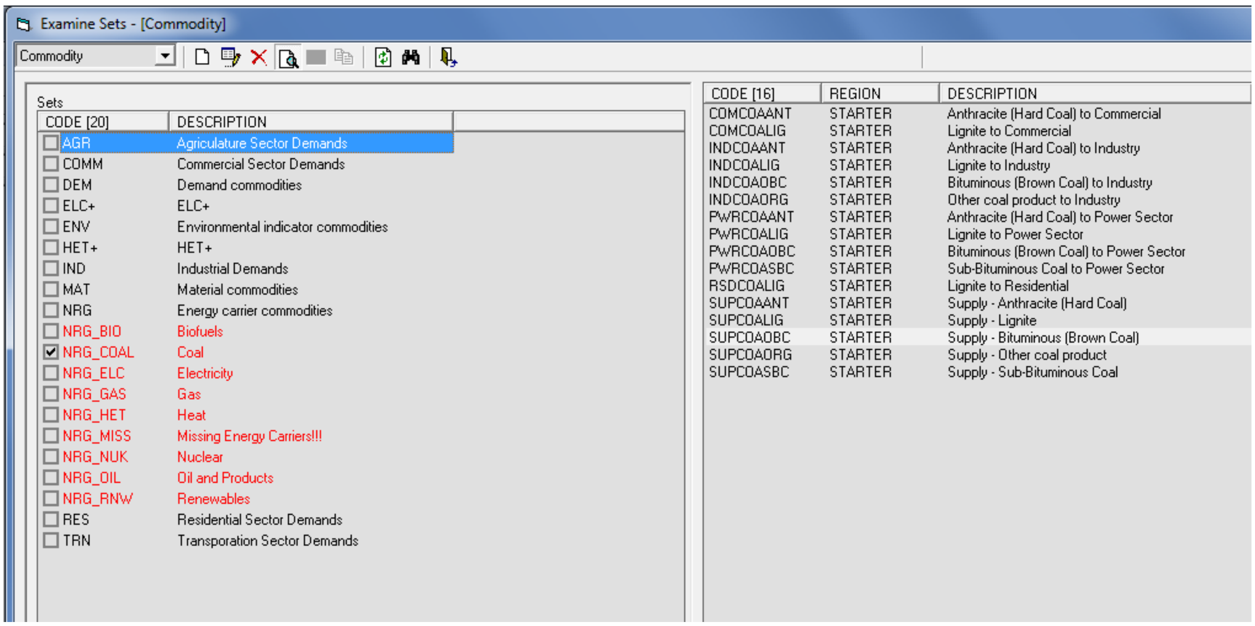
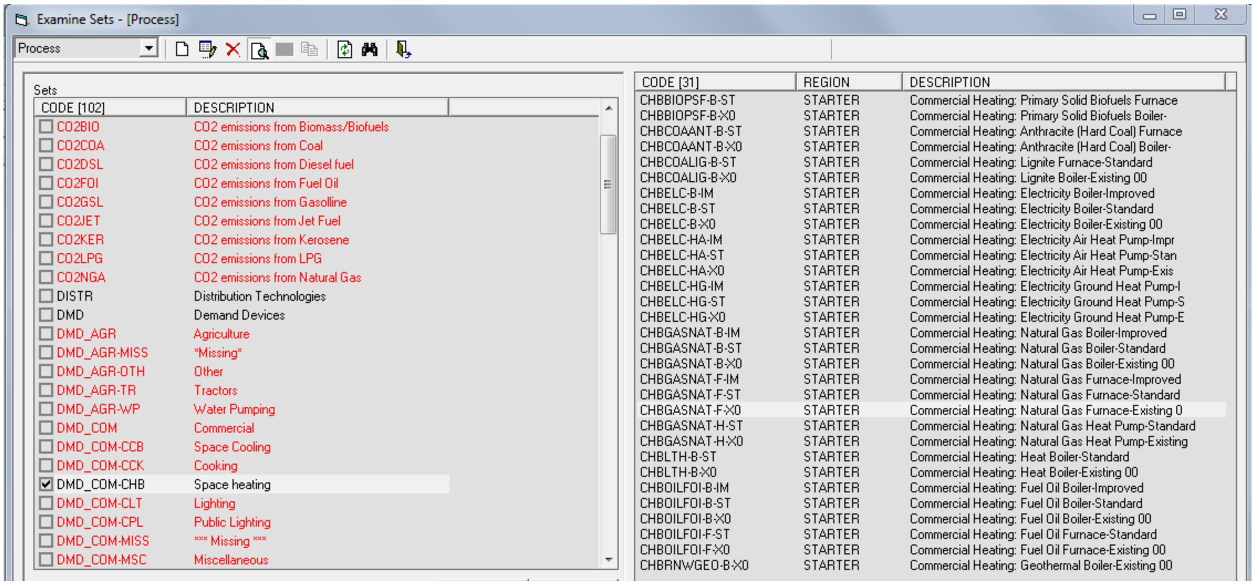
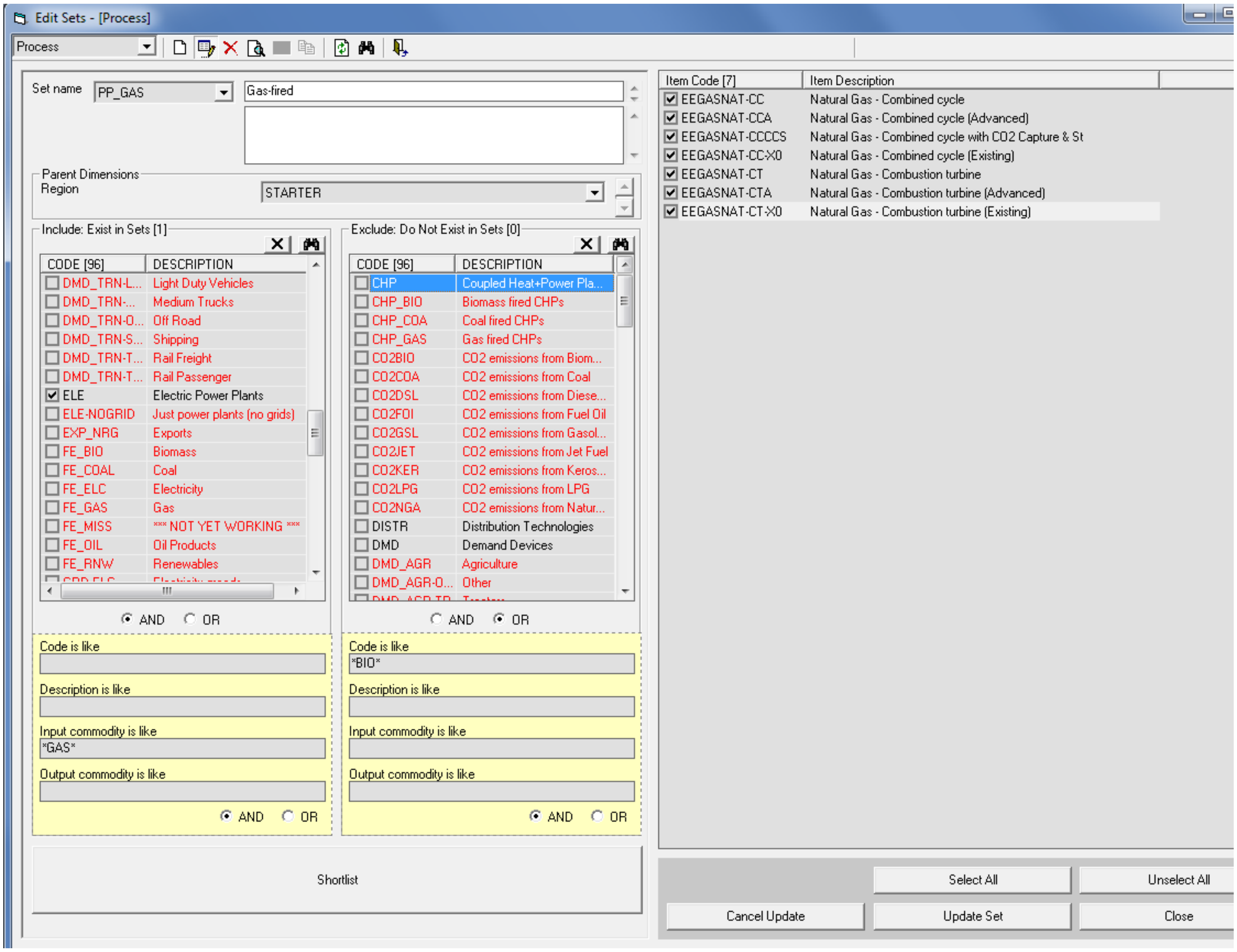


Figure 66: TIMES-Starter VBE Process Sets (Partial List)




Sets are built by specifying the "rules" that properly identify all of the appropriate entities to be included in that set by means the VBE Edit Sets form, and only those elements, as shown in Figure 67. The set shown, PP_GAS, is the set of all gas-fired power plants, and it is specified as process belonging to the set ELE with input commodity names that include GAS anywhere in the name, but exclude any input commodities that also have BIO in their name. Note that the process (or commodity) name, description, and output commodity can also be used when specifying set rules.

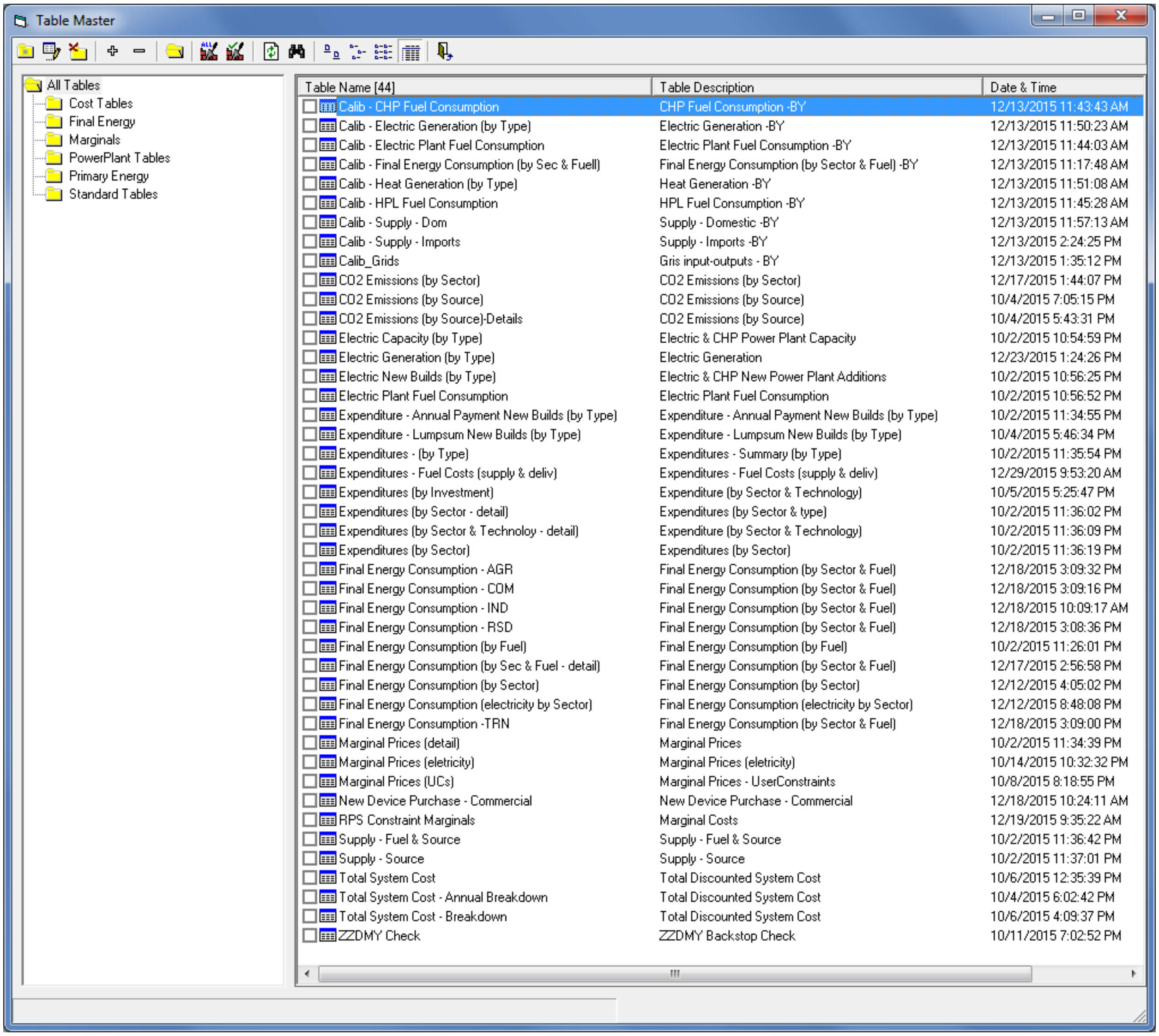
**Figure 67: VBE Process Set Specification**



## 12.2 TIMES-Starter VBE Tables

The VBE database that comes with the Starter model includes a full set of energy systems analysis tables as shown in Figure 68. These tables have also been organized into subsets for Costs, Final Energy, Marginals, Power Plants, and Primary Energy by means of the VBE Table Master facility shown in the figure.

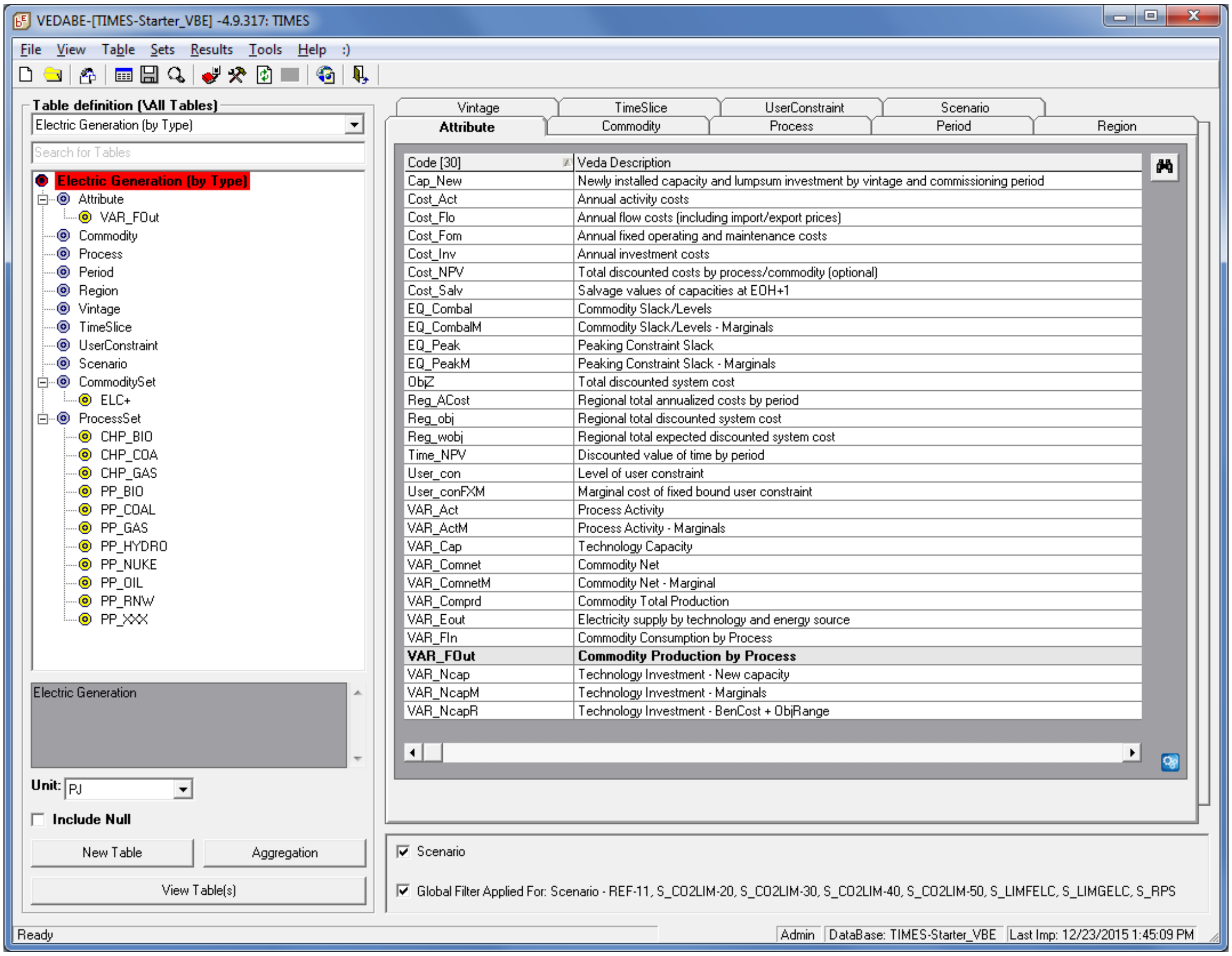
Figure 68: TIMES-Starter List of Tables




| Table Name [44] | Table Description | Date & Time |
|---|---|---|
| Calib - CHP Fuel Consumption | CHP Fuel Consumption -BY | 12/13/2015 11:43:43 AM |
| Calib - Electric Generation (by Type) | Electric Generation -BY | 12/13/2015 11:50:23 AM |
| Calib - Electric Plant Fuel Consumption | Electric Plant Fuel Consumption -BY | 12/13/2015 11:44:03 AM |
| Calib - Final Energy Consumption (by Sec & Fuel) | Final Energy Consumption (by Sector & Fuel) -BY | 12/13/2015 11:17:48 AM |
| Calib - Heat Generation (by Type) | Heat Generation -BY | 12/13/2015 11:51:08 AM |
| Calib - HPL Fuel Consumption | HPL Fuel Consumption -BY | 12/13/2015 11:45:28 AM |
| Calib - Supply - Dom | Supply - Domestic -BY | 12/13/2015 11:57:13 AM |
| Calib - Supply - Imports | Supply - Imports -BY | 12/13/2015 2:24:25 PM |
| Calib_Grids | Gris input-outputs - BY | 12/13/2015 1:35:12 PM |
| CO2 Emissions (by Sector) | CO2 Emissions (by Sector) | 12/17/2015 1:44:07 PM |
| CO2 Emissions (by Source) | CO2 Emissions (by Source) | 10/4/2015 7:05:15 PM |
| CO2 Emissions (by Source)-Details | CO2 Emissions (by Source) | 10/4/2015 5:43:31 PM |
| Electric Capacity (by Type) | Electric & CHP Power Plant Capacity | 10/2/2015 10:54:59 PM |
| Electric Generation (by Type) | Electric Generation | 12/23/2015 1:24:26 PM |
| Electric New Builds (by Type) | Electric & CHP New Power Plant Additions | 10/2/2015 10:56:25 PM |
| Electric Plant Fuel Consumption | Electric Plant Fuel Consumption | 10/2/2015 10:56:52 PM |
| Expenditure - Annual Payment New Builds (by Type) | Expenditure - Annual Payment New Builds (by Type) | 10/2/2015 11:34:55 PM |
| Expenditure - Lumpsum New Builds (by Type) | Expenditure - Lumpsum New Builds (by Type) | 10/4/2015 5:46:34 PM |
| Expenditures - (by Type) | Expenditures - Summary (by Type) | 10/2/2015 11:35:54 PM |
| Expenditures - Fuel Costs (supply & deliv) | Expenditures - Fuel Costs (supply & deliv) | 12/29/2015 9:53:20 AM |
| Expenditures (by Investment) | Expenditure (by Sector & Technology) | 10/5/2015 5:25:47 PM |
| Expenditures (by Sector - detail) | Expenditures (by Sector & type) | 10/2/2015 11:36:02 PM |
| Expenditures (by Sector & Technoloy - detail) | Expenditure (by Sector & Technology) | 10/2/2015 11:36:09 PM |
| Expenditures (by Sector) | Expenditures (by Sector) | 10/2/2015 11:36:19 PM |
| Final Energy Consumption - AGR | Final Energy Consumption (by Sector & Fuel) | 12/18/2015 3:09:32 PM |
| Final Energy Consumption - COM | Final Energy Consumption (by Sector & Fuel) | 12/18/2015 3:09:16 PM |
| Final Energy Consumption - IND | Final Energy Consumption (by Sector & Fuel) | 12/18/2015 10:09:17 AM |
| Final Energy Consumption - RSD | Final Energy Consumption (by Sector & Fuel) | 12/18/2015 3:08:36 PM |
| Final Energy Consumption (by Fuel) | Final Energy Consumption (by Fuel) | 10/2/2015 11:26:01 PM |
| Final Energy Consumption (by Sec & Fuel - detail) | Final Energy Consumption (by Sector & Fuel) | 12/17/2015 2:56:58 PM |
| Final Energy Consumption (by Sector) | Final Energy Consumption (by Sector) | 12/12/2015 4:05:02 PM |
| Final Energy Consumption (electricity by Sector) | Final Energy Consumption (electricity by Sector) | 12/12/2015 8:48:08 PM |
| Final Energy Consumption -TRN | Final Energy Consumption (by Sector & Fuel) | 12/18/2015 3:09:00 PM |
| Marginal Prices (detail) | Marginal Prices | 10/2/2015 11:34:39 PM |
| Marginal Prices (eletricity) | Marginal Prices (eletricity) | 10/14/2015 10:32:32 PM |
| Marginal Prices (UCs) | Marginal Prices - UserConstraints | 10/8/2015 8:18:55 PM |
| New Device Purchase - Commercial | New Device Purchase - Commercial | 12/18/2015 10:24:11 AM |
| RPS Constraint Marginals | Marginal Costs | 12/19/2015 9:35:22 AM |
| Supply - Fuel & Source | Supply - Fuel & Source | 10/2/2015 11:36:42 PM |
| Supply - Source | Supply - Source | 10/2/2015 11:37:01 PM |
| Total System Cost | Total Discounted System Cost | 10/6/2015 12:35:39 PM |
| Total System Cost - Annual Breakdown | Total Discounted System Cost | 10/4/2015 6:02:42 PM |
| Total System Cost - Breakdown | Total Discounted System Cost | 10/6/2015 4:09:37 PM |
| ZZDMY Check | ZZDMY Backstop Check | 10/11/2015 7:02:52 PM |

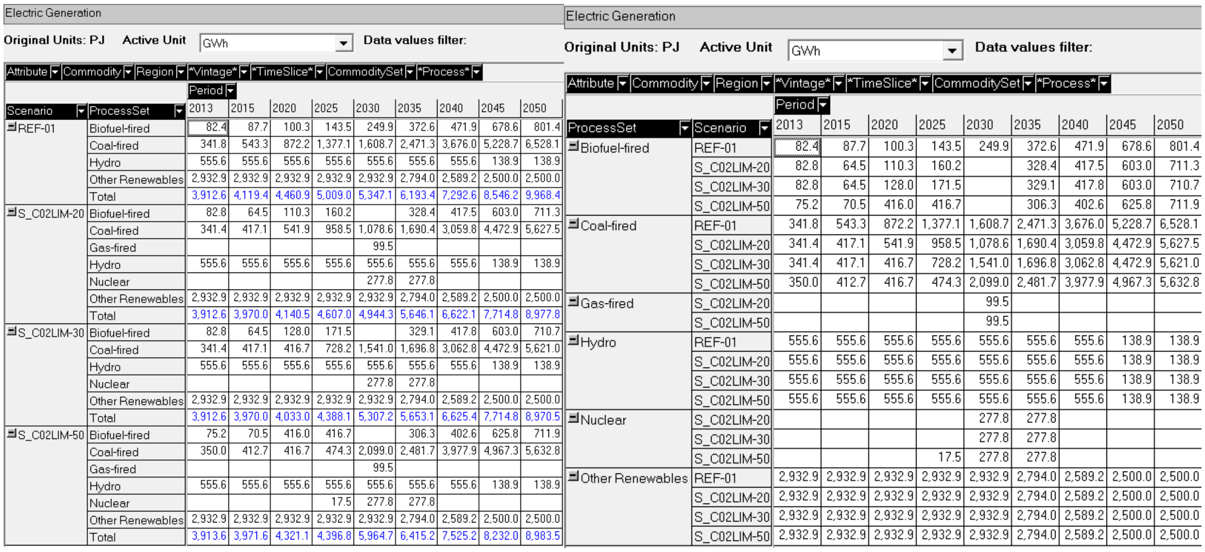
Tables are built in VBE by specifying the Attribute(s), which correspond to the desired model results, and the commodity and process Sets for which these results are to be organized and presented. Figure 69 presents the VBE Table specification form, which also oversees requesting preparation of the table for viewing, for the Table: Electricity Generation (by Type). The Atttribute VAR_FOut is commodity production from a process, the commodity specified is electricity (so as to avoid heat from the CHPs and any emissions perhaps accounted for at the power plant level (for CCS)), and the specified process sets give a breakdown for power plants and combined heat and power plants by fuel type. Note that PP_XXX is a null set that is designed to catch naming convention errors. Its includes the set of all power plants, but it excludes all the power plant subsets, so that if a power plant technology is added to the model, but does not get allocated to a subset, it will show in this null set as a flag to the user to properly define this process's subset – though it is expected to always not appear in the actual table presented in the cube.

**Figure 69: VBE Table Specification for Electricity Generation by Fuel Type**




Any of the existing tables can be viewed in the VBE dynamic data cube environment, as shown in Figure 70. VBE allows the analyst to dissect and reorganize the model results in order to determine the impacts of different model assumptions – here moving scenarios to the right so as to easily see where results have changed. Furthermore, as discussed in Section 13, the VBE tables can be exported to Excel, and in particular the AnalyticsXLS assembled for the TIMES-Starter model that presents multi-case comparison graphs to facilitate visualizing these impacts.

**Figure 70: VBE Data Cube View**



Electric Generation

Original Units: PJ Active Unit GWh Data values filter:

Attribute | Commodity | Region | *Vintage* | *TimeSlice* | CommoditySet | *Process*

| Scenario | ProcessSet | 2013 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|---|---|
| REF-01 | Biofuel-fired | 82.4 | 87.7 | 100.3 | 143.5 | 249.9 | 372.6 | 471.9 | 678.6 | 801.4 |
| | Coal-fired | 341.8 | 543.3 | 872.2 | 1,377.1 | 1,608.7 | 2,471.3 | 3,676.0 | 5,228.7 | 6,528.1 |
| | Hydro | 555.6 | 555.6 | 555.6 | 555.6 | 555.6 | 555.6 | 555.6 | 138.9 | 138.9 |
| | Other Renewables | 2,932.9 | 2,932.9 | 2,932.9 | 2,932.9 | 2,932.9 | 2,794.0 | 2,589.2 | 2,500.0 | 2,500.0 |
| | Total | 3,912.6 | 4,119.4 | 4,460.9 | 5,009.0 | 5,347.1 | 6,193.4 | 7,292.6 | 8,546.2 | 9,968.4 |
| S_C02LIM-20 | Biofuel-fired | 82.8 | 64.5 | 110.3 | 160.2 | | 328.4 | 417.5 | 603.0 | 711.3 |
| | Coal-fired | 341.4 | 417.1 | 541.9 | 958.5 | 1,078.6 | 1,690.4 | 3,059.8 | 4,472.9 | 5,627.5 |
| | Gas-fired | | | | | 99.5 | | | | |
| | Hydro | 555.6 | 555.6 | 555.6 | 555.6 | 555.6 | 555.6 | 555.6 | 138.9 | 138.9 |
| | Nuclear | | | | | 277.8 | 277.8 | | | |
| | Other Renewables | 2,932.9 | 2,932.9 | 2,932.9 | 2,932.9 | 2,932.9 | 2,794.0 | 2,589.2 | 2,500.0 | 2,500.0 |
| | Total | 3,912.6 | 3,970.0 | 4,140.5 | 4,607.0 | 4,944.3 | 5,646.1 | 6,622.1 | 7,714.8 | 8,977.8 |
| S_C02LIM-30 | Biofuel-fired | 82.8 | 64.5 | 128.0 | 171.5 | | 329.1 | 417.8 | 603.0 | 710.7 |
| | Coal-fired | 341.4 | 417.1 | 416.7 | 728.2 | 1,541.0 | 1,696.8 | 3,062.8 | 4,472.9 | 5,621.0 |
| | Hydro | 555.6 | 555.6 | 555.6 | 555.6 | 555.6 | 555.6 | 555.6 | 138.9 | 138.9 |
| | Nuclear | | | | | 277.8 | 277.8 | | | |
| | Other Renewables | 2,932.9 | 2,932.9 | 2,932.9 | 2,932.9 | 2,932.9 | 2,794.0 | 2,589.2 | 2,500.0 | 2,500.0 |
| | Total | 3,912.6 | 3,970.0 | 4,033.0 | 4,388.1 | 5,307.2 | 5,653.1 | 6,625.4 | 7,714.8 | 8,970.5 |
| S_C02LIM-50 | Biofuel-fired | 75.2 | 70.5 | 416.0 | 416.7 | | 306.3 | 402.6 | 625.8 | 711.9 |
| | Coal-fired | 350.0 | 412.7 | 416.7 | 474.3 | 2,099.0 | 2,481.7 | 3,977.9 | 4,967.3 | 5,632.8 |
| | Gas-fired | | | | | 99.5 | | | | |
| | Hydro | 555.6 | 555.6 | 555.6 | 555.6 | 555.6 | 555.6 | 555.6 | 138.9 | 138.9 |
| | Nuclear | | | | 17.5 | 277.8 | 277.8 | | | |
| | Other Renewables | 2,932.9 | 2,932.9 | 2,932.9 | 2,932.9 | 2,932.9 | 2,794.0 | 2,589.2 | 2,500.0 | 2,500.0 |
| | Total | 3,913.6 | 3,971.6 | 4,321.1 | 4,396.8 | 5,964.7 | 6,415.2 | 7,525.2 | 8,232.0 | 8,983.5 |

Electric Generation

Original Units: PJ Active Unit GWh Data values filter:

Attribute | Commodity | Region | *Vintage* | *TimeSlice* | CommoditySet | *Process*

| ProcessSet | Scenario | 2013 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|---|---|
| Biofuel-fired | REF-01 | 82.4 | 87.7 | 100.3 | 143.5 | 249.9 | 372.6 | 471.9 | 678.6 | 801.4 |
| | S_C02LIM-20 | 82.8 | 64.5 | 110.3 | 160.2 | | 328.4 | 417.5 | 603.0 | 711.3 |
| | S_C02LIM-30 | 82.8 | 64.5 | 128.0 | 171.5 | | 329.1 | 417.8 | 603.0 | 710.7 |
| | S_C02LIM-50 | 75.2 | 70.5 | 416.0 | 416.7 | | 306.3 | 402.6 | 625.8 | 711.9 |
| Coal-fired | REF-01 | 341.8 | 543.3 | 872.2 | 1,377.1 | 1,608.7 | 2,471.3 | 3,676.0 | 5,228.7 | 6,528.1 |
| | S_C02LIM-20 | 341.4 | 417.1 | 541.9 | 958.5 | 1,078.6 | 1,690.4 | 3,059.8 | 4,472.9 | 5,627.5 |
| | S_C02LIM-30 | 341.4 | 417.1 | 416.7 | 728.2 | 1,541.0 | 1,696.8 | 3,062.8 | 4,472.9 | 5,621.0 |
| | S_C02LIM-50 | 350.0 | 412.7 | 416.7 | 474.3 | 2,099.0 | 2,481.7 | 3,977.9 | 4,967.3 | 5,632.8 |
| Gas-fired | S_C02LIM-20 | | | | | 99.5 | | | | |
| | S_C02LIM-50 | | | | | 99.5 | | | | |
| Hydro | REF-01 | 555.6 | 555.6 | 555.6 | 555.6 | 555.6 | 555.6 | 555.6 | 138.9 | 138.9 |
| | S_C02LIM-20 | 555.6 | 555.6 | 555.6 | 555.6 | 555.6 | 555.6 | 555.6 | 138.9 | 138.9 |
| | S_C02LIM-30 | 555.6 | 555.6 | 555.6 | 555.6 | 555.6 | 555.6 | 555.6 | 138.9 | 138.9 |
| | S_C02LIM-50 | 555.6 | 555.6 | 555.6 | 555.6 | 555.6 | 555.6 | 555.6 | 138.9 | 138.9 |
| Nuclear | S_C02LIM-20 | | | | | 277.8 | 277.8 | | | |
| | S_C02LIM-30 | | | | | 277.8 | 277.8 | | | |
| | S_C02LIM-50 | | | | 17.5 | 277.8 | 277.8 | | | |
| Other Renewables | REF-01 | 2,932.9 | 2,932.9 | 2,932.9 | 2,932.9 | 2,932.9 | 2,794.0 | 2,589.2 | 2,500.0 | 2,500.0 |
| | S_C02LIM-20 | 2,932.9 | 2,932.9 | 2,932.9 | 2,932.9 | 2,932.9 | 2,794.0 | 2,589.2 | 2,500.0 | 2,500.0 |
| | S_C02LIM-30 | 2,932.9 | 2,932.9 | 2,932.9 | 2,932.9 | 2,932.9 | 2,794.0 | 2,589.2 | 2,500.0 | 2,500.0 |
| | S_C02LIM-50 | 2,932.9 | 2,932.9 | 2,932.9 | 2,932.9 | 2,932.9 | 2,794.0 | 2,589.2 | 2,500.0 | 2,500.0 |

**Note** that for Commercial and Residential Heat Pumps while the output is properly report separately for heating and cooling demands, the fuel consumption to end-use services puts the total electric and/gas against the heating demand. Only by further processing the tables taking into consideration the amount of each demand serviced by the heat pump and the device efficiencies for each can the final energy consumed be apportioned properly to each end-use service.

An important and often used feature of VBE is the Global Filter, which enables temporary filters to be applied outside of any specification embodied in the table definition. This is most often used for Scenarios to facilitate focusing in on a subset of the scenarios. A second commonly used Global Filter is for Periods, when one is not interested in seeing results for all the periods in a run.

Once fluent in the use of VBE, users can create new Sets and Tables as needed for a particular analysis (see the ANSWER VBE manual).

# 13 Using the Analytics Results Comparison Graphing Workbook

The Analytics Results Comparison Graphing Workbook (AnalyticsXLS) is a VBA-enabled Excel workbook that allows a full set of analysis scenario results to be stored, updated and viewed according to smaller subsets for analyzing model results and preparing report and presentation quality graphics of model results. The VBE Update Excel tool is used to automatically update the results tables in the AnalyticsXLS whenever new or updated model run results are available. The DWG-Analytics "Smart" Excel Workbook User's Guide provides a complete description of how to effectively work with the AnalyticsXLS.

## 13.1 AnalyticsXLS Graphing Tables

Table 10 provides the complete list of the AnalyticsXLS (AXLS) tables currently developed for the TIMES-Starter model. In general, each sheet presents one set of model results for whatever combination of scenarios is selected. The model results for each table are first assembled on so-called “VEDA Dump” sheets, as also designated in Table 10, which correspond directly (and identically) with the associated VBE table. The Index sheet in the AXLS, corresponding to the table below, provides links to each graph comparison sheet and dump table.

**Table 10: List of AnalyticsXLS Tables for TIMES-Starter**

| Sheet Name & Link | Description | Dump Sheet Location & Link |
|---|---|---|
| Scenarios | Control sheet with all Scenarios | NA |
| Metrics 2030 | Aggregate result metrics to 2030 | NA |
| Metrics 2050 | Aggregate result metrics to 2050 | NA |
| System cost | Total discounted system cost (Objective Function) | VEDA Dump_Cost |
| Annual System Cost | Annual undiscounted components of the system cost | VEDA Dump_Cost |
| System Cost Breakdown | Components of the Total discounted system cost | VEDA Dump_Cost |
| Primary energy_ByFuel | Primary energy by fuel | VEDA Dump_Energy |
| Primary energy_Source | Primary energy by domestic or imports | VEDA Dump_Energy |
| Electricity generation_fuel | Electricity generation by fuel | VEDA Dump_Energy |
| Electricity capacity_fuel | Electricity capacity by fuel | VEDA Dump_Energy |
| Electric Power plant Builds | Capacity of new electric power plants | VEDA Dump_Energy |
| Power plant fuel use | Fuel use by all types of power plants | VEDA Dump_Energy |
| Final energy_Fuel | Final energy use by fuel type | VEDA Dump_Energy |
| Final energy_Sector | Final energy use by fuel type | VEDA Dump_Energy |
| CO2 Emissions_Sector | CO2 Emissions by sector | VEDA Dump_Emissions |
| CO2 Emissions_Fuel | CO2 Emissions by fuel used | VEDA Dump_Emissions |
| Expenditure - Summary | Summary of Total Annual Expenditures | NA |
| Expenditure_Type | Activity and O&M Costs | VEDA Dump_Cost |
| Expenditure_Investment | Investment expenditures by supply and demand sectors | VEDA Dump_Cost |
| Fuel Expenditure | Fuel Expenditures | VEDA Dump_Cost |
| Power Plant investment | Electricity powerplant newbuild investment | VEDA Dump_Cost |
| Sector Final energy_AGR | Final Energy Use by Application - AGR | VEDA Dump_Sector |
| Sector Final energy_COM | Final Energy Use by Application - COM | VEDA Dump_Sector |
| Sector Final energy_IND | Not Included yet | VEDA Dump_Sector |
| Sector Final energy_RSD | Final Energy Use by Application - RSD | VEDA Dump_Sector |
| Sector Final energy_TRN | Final Energy Use by Application - TRN | VEDA Dump_Sector |

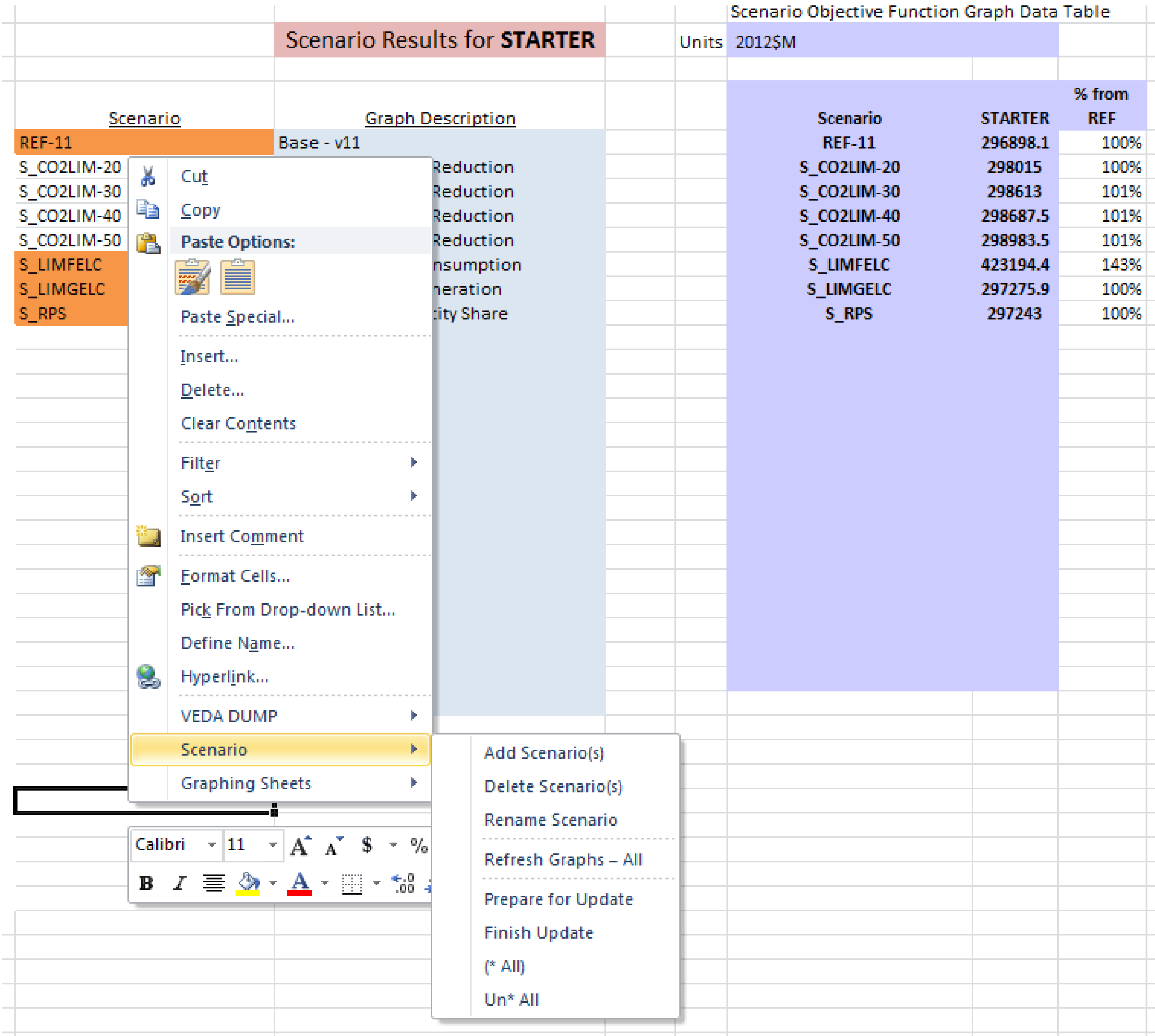
## 13.2 Managing Scenarios

The definition, addition, deletion and updating of scenario results is all done from the Scenarios tab, which contains the complete list of loaded scenarios. These include the current Reference scenario and each of the example policy scenarios. The AXLS scenario management features are accessed through a right click anywhere in the Scenarios tab, as shown in Figure 71. These commands allow scenarios to be added, deleted and renamed, and allow for the scenario results to be updated for all or only selected scenarios. The VBE Update Excel facility also allows for updating of all tables in the workbook, or only selected tables as specified in the Update Excel facility.

As also shown in Figure 71, the Scenarios tab shows (through orange color coding) which scenarios are selected for graphing, and the Refresh Graphs - All command is used to change this selection. Prepare for Update allows selective scenario updating by not updating any scenario when a “star” is placed next to the scenario name in col-A, in which case the user most also remember to set the VBE Global Filter accordingly. Finish Update undoes that process. See User’s guide for detailed steps for updating the workbook.

**Note** that the VBE UpdateXLS functions is quite demanding and may take some time to perform the update operation. The Prepare for Update feature also changes Formula Calculation Options to Manual which greatly reduces the time the update takes. The Finish Update switches this back to Automatic refreshing all the links, formulas and thereby graphs in the workbook.

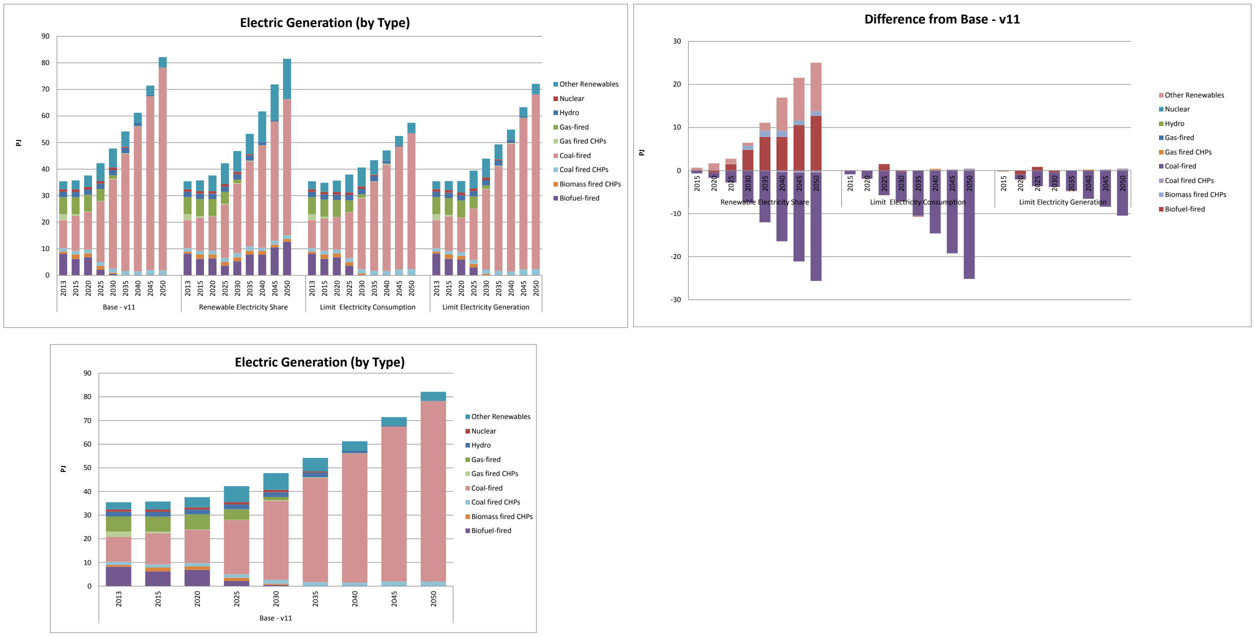
**Figure 71: Screenshot of AnalyticsXLS Scenarios tab**



## 13.3 Example Graphing Sheets

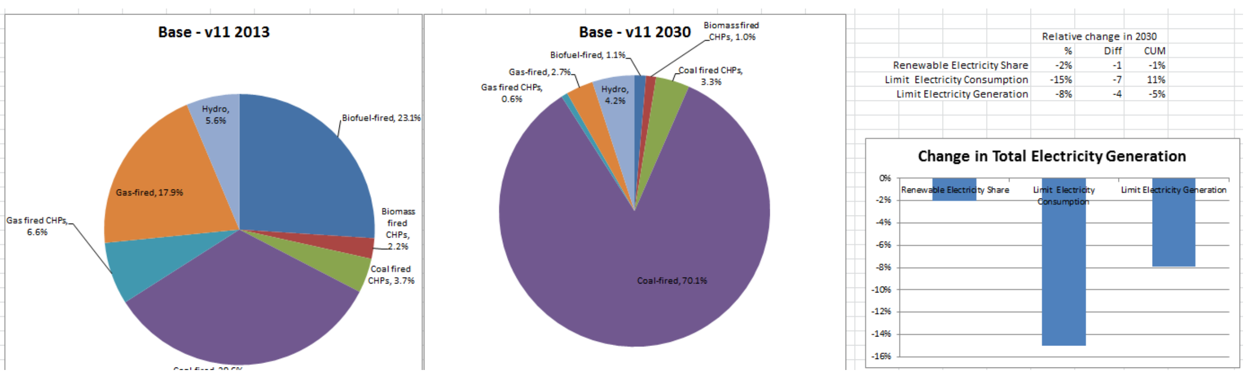
The graphing sheets present their results in both tabular and chart form, Figure 72 shows the charts for Electricity Generation by Plant Type. The Reference scenario (1st one) is graphed separately and in combination with three other scenarios, and the difference between the scenarios and the Reference is also graphed.

Figure 72: Screenshot of AnalyticsXLS Graphing Sheet - 1




The graphing sheets also present pie charts that show how each scenario changes over time, and a bar chart that compares other overall changes between scenarios, as shown in Figure 73.

Figure 73: Screenshot of AnalyticsXLS Graphing Sheet - 2




## 13.4 Metrics Tables

There are two Metrics tabs which calculate cumulative results for selected model parameters out to 2030 and out to 2050. Figure 74 shows the cumulative metrics selected for the Starter model, which includes Total System Cost, Primary Energy Supply, Electricity Generation, Final Energy Consumption, New Power Plant Builds, Investment in New Power Plant Capacity, Fuel Expenditures, and $CO_2$ Emissions. The cumulative values are calculated from each respective graphing sheet, with care taken to accommodate the variable length (in rows 2-3) and number of periods, and to properly account for annual values versus per period results.

### Figure 74: Cumulative Metrics Tables to 2030

| Scenario | System Cost | |
|---|---|---|
| | 2012$M | % Difference |
| Base - v11 | 109,937 | |
| Renewable Electricity Share | 109,874 | -0.1% |
| Limit Electricity Consumption | 111,223 | 1.2% |
| Limit Electricity Generation | 110,073 | 0.1% |

| Scenario | Power Plant Builds | |
|---|---|---|
| | GW | % Difference |
| Base - v11 | 1.28 | |
| Renewable Electricity Share | 1.21 | 94.7% |
| Limit Electricity Consumption | 0.96 | 75.1% |
| Limit Electricity Generation | 1.07 | 83.9% |

| Scenario | Primary Energy | |
|---|---|---|
| | PJ | % Difference |
| Base - v11 | 5,245 | |
| Renewable Electricity Share | 5,226 | -0.4% |
| Limit Electricity Consumption | 5,322 | 1.5% |
| Limit Electricity Generation | 5,163 | -1.6% |

| Scenario | Electricity Investment | |
|---|---|---|
| | 2012$M | % Difference |
| Base - v11 | 3,190 | |
| Renewable Electricity Share | 2,907 | -8.9% |
| Limit Electricity Consumption | 2,472 | -22.5% |
| Limit Electricity Generation | 2,817 | -11.7% |

| Scenario | Electrity Generation | |
|---|---|---|
| | PJ | % Difference |
| Base - v11 | 21 | |
| Renewable Electricity Share | 21 | 0.0% |
| Limit Electricity Consumption | 21 | 0.0% |
| Limit Electricity Generation | 21 | 0.0% |

| Scenario | Fuel Expenditures | |
|---|---|---|
| | 2012$M | % Difference |
| Base - v11 | 50,163 | |
| Renewable Electricity Share | 49,997 | -0.3% |
| Limit Electricity Consumption | 52,462 | 4.6% |
| Limit Electricity Generation | 50,098 | -0.1% |

| Scenario | Final Energy Consumption | |
|---|---|---|
| | PJ | % Difference |
| Base - v11 | 2,489 | |
| Renewable Electricity Share | 2,485 | -0.2% |
| Limit Electricity Consumption | 2,673 | 7.4% |
| Limit Electricity Generation | 2,484 | -0.2% |

| Scenario | CO2 Emissions | |
|---|---|---|
| | kt | % Difference |
| Base - v11 | 293,340 | |
| Renewable Electricity Share | 278,965 | -4.9% |
| Limit Electricity Consumption | 288,736 | -1.6% |
| Limit Electricity Generation | 284,537 | -3.0% |

Because these metric results are refreshed each time a new set of scenarios is selected, each Metrics tab also contains an Archive section, where updated results for each scenario can be saved using Copy/Paste Values to create a table with the complete set of results for all the scenarios in the workbook.

# 14 Procedures for Adapting TIMES-Starter

The TIMES-Starter model comprises all the modeling components necessary to build a model relevant to most any study area. However, it is only the starting point and besides the calibration activities discussed in Section 6, a series of steps needs to be followed to prepare the Starter model for the new situation. Each of the basic steps are described in this Section.

## 14.1 Changing Country Name

The first thing that one needs to do is establish the name of the study area, which for now we'll assume is a <country>. To accomplish this the following steps should be undertaking in the order listed.

1. Copy the TIMES-Starter folder to another folder name under the Answer_Databases folder.
2. Rename the TIMES-Starter(vXX).MDB to TIMES- <country>(v01).MDB.
3. Open the TIMES-<country>(vXX) database & edit the Region name, changing STARTER to <country>.
4. Repeat steps 2 and 3 for the TIMES-Starter(vXXxls).MDB for each region.
5. Replace **Starter** with <country> in the name of each of the templates.
6. In the EB_<country> (2013) template change **Starter** to <country> in cell B1 on the Energy balance tab
7. Open each XLS
    a. Go to Data/Edit Links and change the references from EB_Starter to the EB_<country>, as well as any other XLS linked to according to the relationship shown in Figure 1.
    b. Make sure the <country> is now reflected on the Setup sheet, so appears as the Region on each ANSWER load sheet.
    c. save each XLS.
8. Open the <country>(vXX) database & reimport EACH scenarios, specifying the <country> XLSs instead of the now missing Starter XLSs.
9. Try a test run to replicate the REFxx already in the database.
10. In ANSWER remove the old model runs, keeping the definitions --- if desired.

With that your model is now ready for customizing to your area of study.

## 14.2 Customizing TIMES-Starter for Your Model

The roadmap to customize the TIMES-Starter for your situation entails each of the steps listed below. All the input data templates associated with each of the steps, and how to work with them, has been described earlier, so this just serves as a sequenced recommended checklist for getting your model set up. It is recommended that this process be undertaken slowly and carefully following sequentially the steps listed below. For each step the relevant template(s) and key sheets for that action are noted.

### 14.2.1 Changing Units, Periods and Timeslices *{Pending}*

For now users should stick with the Units, Periods and timeslices in the TIMES-Starter. In principle all these can be adjusted, but this will be addressed in a later version of the Starter model.

### 14.2.2 Adding New Commodities and Processes

The TIMES-Starter, when complete, will have a wide range of commodities and processes for most every situation. However, there may be unforeseen circumstances requiring the addition of a commodity/process. To insert a new commodity/process simply copy/insert a like element on the SETUP sheet of the relevant template and adjust the $cell references to grab the right characters to properly formulate the item name and description. The process is then to add to the declaration sheet and data sheets, adjusting their reference to SETUP if/as necessary. Then to adjust the RES connectivity, on the data sheet either use the "smart" buttons to grab the input and output commodities from the declaration sheets, copy them from another process, or link them manually yourself, then complete the data requirements as appropriate. If additional parameters are needed for any item they can be freely added to the end of the associated ProcData sheet. Also, if adding an existing process with base year installed capacity to the model, it should be appropriately reflected on the BY Calibration sheet. This is valid for all sectors.

The other, perhaps simpler, approach would be to usurp an existing Commodity/Process by simply changing the way its name/description are assembled, and adjusting data as appropriate. The only downside of this approach is that you are thereby breaking the connection with the US9r source data for that item.

**Caution With Respect to Changing Component Names and Adding Sub-sectors**

While the templates are set up to enable the user to change the names of commodities and technologies this is **HIGHLY DISCOURAGED** since the rules that govern the many ANSWER named TechFilters and VBE Set definitions (and perhaps Table structures) are based upon the TIMES-Starter conventions!!! Therefore, while the user is certainly free to include/exclude components, special care and in-depth understanding of the TechFilters and VBE Sets governing the model is essential before embarking on such an adventure.

When introducing a new sub-sector, consideration will also need to be given to updating and/or replicating the ANSWER TechFilters and VBE Sets as well!!!

Also, note that some resources supply options in the AT_<region>_SUP template require the user to put in local prices for them to work appropriately.

### 14.2.3 Setup and Calibration

Model setup and calibration were discussed in the earlier in Calibration section for each sector. The points here are listed as a reminder for the steps to be undertaken.

1. Plug in your energy balance [EB_<country>(year)];
2. Adjust the periods and timeslices [LoadCalibration, then copied into EB_<country>(TimePeriods)]
3. Tailor the RES to your situation by eliminating and perhaps adding commodities/process not of interest/relevant or missing [SUP/BY/NT_<sector>(SETUP)];
4. Adjust the Calibration sheets, and
5. Run for 1 period refining the calibration by adjusting the EB and Calibration sheets.

### 14.2.4 Ready the Reference Scenario

Preparing the Reference Scenario was discussed in the earlier in Section 10. The points here are listed as a reminder of the steps to be undertaken, but refer to said section for specifics.

1. Adjust the energy price prices and potential/physical limits on resources and electricity/gas infrastructure [SUP(SupplyPrice/Potential+Grid&Pipeline)]
2. Adjust the demand drivers [Demand-REF(drivers)];
3. Introduce and forces operations [REF_BOUNDLO(ForceOp), and all known coming new builds (and NCAP_BND in the appropriate workbook, NT-PP in particular) ;
4. Review and adjust the Reference guidance mechanisms (fuel switching & rate of new technology penetration controls, as described in Section 10) [UC_*];
5. Introduce all known/on the books future policies [REF_POL(Policies)];
6. Run and refine the Reference scenario.
7. Make any necessary adjustments to the VBE SnT (and AXLS), (although this is likely not necessary unless names of commodities/technologies have been changed.

#### 14.2.5 Try some Policy Scenarios

Trying policy runs was discussed in the earlier in Section 11. The points here are listed as a reminder of the steps to be undertaken, but refer to said section for specifics.

1. Paste your Reference scenario values into the standard policy scenario templates provided (e.g., CO2/EE/RE targets), and adjust the targets as desired.
2. Import the updated scenario files and run the scenarios.
3. Assess the model behavior in VBE and the AXLS.

### 14.3 Handling More than one Region *{Down the Road}*

In principle the design of the Starter model template will readily support the replication of the templates (or sheets in the templates) to enable multi-region models to be assembled.

However, for now users should stick with the single region model, but this will be addressed in a later version of the Starter model by creating a 2-region version of TIMES-Starter.

# 15 Some Advanced TIMES Features *{VFE DemoS examples – Down the Road}*

TIMES is also support by the VEDA Front-End (VFE) model management platform. The training course developed by ETSAP for VFE has a set (more sophisticated) process descriptions and model techniques that can be readily introduced to the TIMES-Starter platform, as a 2nd tier (intermediate) set of scenarios to demonstrate the implementation of each of these with the ANSWER-TIMES and TIMES-Starter environment.

Among the candidate features are:

- CHPs pass-out turbines;
- Lumpy (Discrete) investments / retirement;
- Storage technologies;
- UC growth constraint + UC total;
- Elastic demands;
- Stochastics, and

- Many others.