NATIONAL ENERGY TECHNOLOGY LABORATORY

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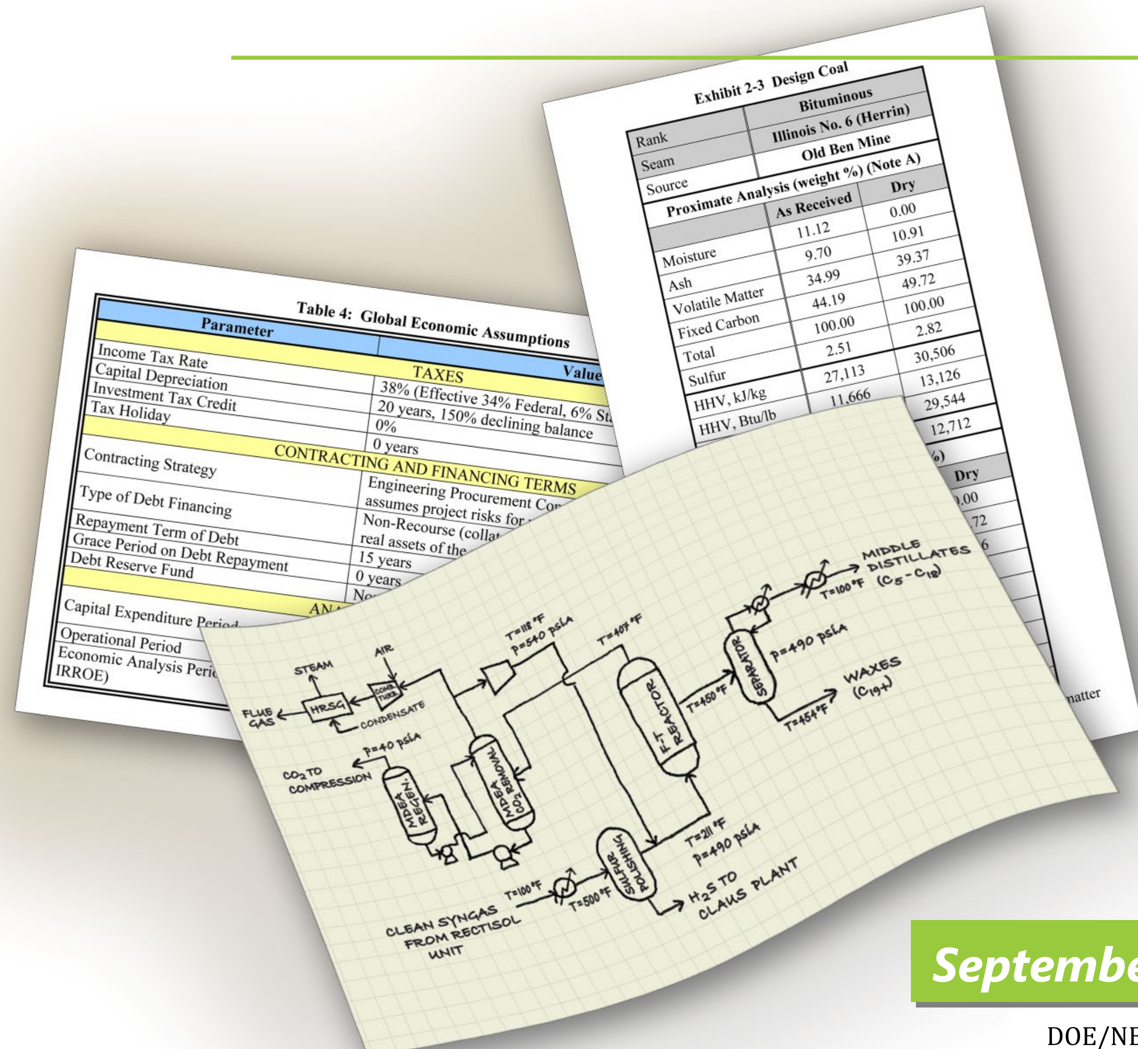
QUALITY GUIDELINES FOR ENERGY SYSTEM STUDIES

Economic Unit Commitment and Dispatch Modeling Guidelines for NETL Studies Version 3.0



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Acronyms and Abbreviations

AEO	Annual Energy Outlook
AESO	Alberta Electric System Operator
BC Hydro	BC Hydro and Power Authority
CAISO	California ISO
CO_2	Carbon dioxide
DOE	Department of Energy
EIA	Energy Information Administration
ERCOT	Electric Reliability Council of Texas
FERC	Federal Energy Regulatory Commission
FRCC	Florida Reliability Coordinating Council
FRED	Federal Reserve Economic Data
Hg	Mercury
ISO	Independent system operator
ISO-NE	ISO-New England
LTRA	Long-Term Reliability Assessment
MEMP	Market Efficiency Modeling Practices
MESA	Mission Execution and Strategic Analysis
MISO	Midcontinent ISO
MOD	Modeling, data, and analytics
NARA	National Archives and Records Administration
NERC	North American Electric Reliability Corporation
NETL	National Energy Technology Laboratory
NOx	Nitrogen oxides
NYISO	New York ISO
PJM	PJM Interconnection
QGESS	Quality Guidelines for Energy System Studies
RTO	Regional transmission organization
SCUC	Security Constrained Unit Commitment
SCED	Security Constrained Economic Dispatch
SO_2	Sulfur dioxide
SPP	Southwest Power Pool
STEO	Short Term Energy Outlook
U.S.	United States

1 Overview

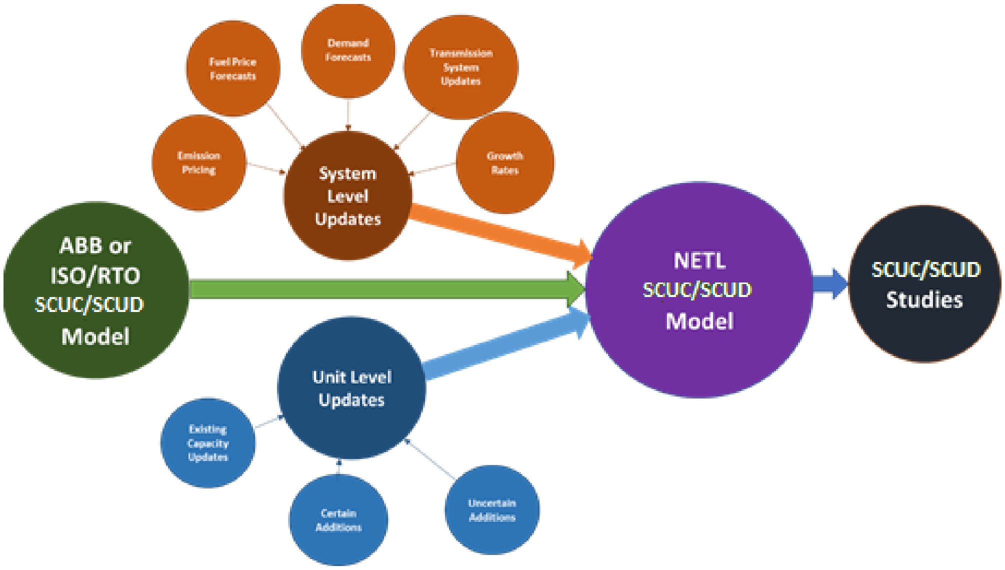
Earlier versions of this document under the title "Quality Guidelines for Energy System Studies (QGESS), *Economic Dispatch Modeling Guidelines for NETL Studies"* provided recommended best practices for building and maintaining security constrained economic unit commitment and dispatch (SCUC/SCUD) models. This document includes small revisions to discuss modeling of gas-electric interdependence. Since the NETL currently utilizes ABB's PROMOD IV™ for SCUC/SCUD modeling, this document refers to that model, however, many of the guidelines are broadly applicable across all SCUC/SCUD models. These guidelines contain data sources for updating and maintaining PROMOD models, as well as guidelines for expanding models when scenarios require. PROMOD modeling guidelines are based upon established industry standards from the PJM Interconnection (PJM) Market Efficiency Modeling Practices (MEMP) (1) and North American Electric Reliability Corporation (NERC) mandatory modeling, data, and analytics (MOD) (2) standards. This document also contains guidance on model data and results, and data retention requirements. The National Energy Technology Laboratory (NETL) recommends these guidelines be followed in the absence of any compelling scenario requirements in order to facilitate comparison of SCUC/SCED studies evaluating the power grid.

The QGESS is a living document as data sources will continually be updated; from time to time, improvements in data and modeling will lead to updating the methodology for performing SCUC/SCUD modeling using PROMOD. In order to maintain consistency, modeling nomenclature will be named by version and sub-version. Versions change when there is a change in the methodology with respect to how SCUC/SCED modeling is performed. A subversion is named when the data sets that are utilized in the models are updated.

2 Security Constrained Unit Commitment/Economic Dispatch Modeling

NETL's modeling guidelines were created using both PJM MEMP and NERC MOD standards in an effort to align with current industry practices. All model maintenance changes and scenario updates will be made, satisfying the set of guidelines detailed in the following sections. When an update to either the PJM MEMP and/or NERC MOD standards is made, NETL will decide whether to adopt the new changes and, if so, release an updated version of the QGESS (Exhibit 1). Feedback on these guidelines are welcomed through submission to the NETL contact listed earlier in this document.

Exhibit 1. Model update process



2.1 Base Model

Simulation-ready data is provided semiannually from ABB through a support service agreement. These data sets contain information on the Eastern Interconnection, Western Interconnection, and the Electric Reliability Council of Texas (ERCOT). The data sets provide all information required to operate a detailed security constrained economic unit commitment and dispatch model. The data gathered by ABB from the Federal Energy Regulatory Commission (FERC), individual independent system operators (ISOs) and regional transmission organizations (RTOs), and other industry sources include a mix of announcements, officially filed data, modeling, and forecasts. Because the official ABB models are published annually, it is necessary to update the provided models with the most recent data available, where relevant.

On occasion, complete models provided by an ISO can be used in place of ABB data. If a model is available, then a decision must be made as to whether the ISO or ABB data will be used. ISO-specific models often contain better predictions of loads and generation than the ABB-provided models, due to the access to non-public ISO internal data. In deciding which data to use, the age of the ISO data must be taken into consideration, as more recent PROMOD data set may be more up to date.

Base data chosen will be documented and the version of the QGESS used will be documented along with the data.

2.2 Generation Growth Rates

The PROMOD model uses growth rates to escalate variables on a monthly or annual basis. These escalation factors are used to grow currency value to the current year, as well as to escalate fuel prices and demands in the absence of specific forecasts. Gross domestic product escalation data comes from the publicly available Federal Reserve Economic Data (FRED) website (3). Demand growth escalation rates are sourced from NERC forecasts (4) and from individual ISO demand forecasts. Growth rates for fuel pricing are sourced from Energy Information Administration (EIA) data contained in the Annual Energy Outlook (AEO) reports (5).

2.3 Demand Forecast Modeling

Demand forecast data for each zone are input in the form of monthly non-coincident peak and energy values. The data represent weather normalized, non-adjusted electricity demand, and include assumptions for energy efficiency and distributed generation. The data is combined with PROMOD internal hourly historical load shapes for each zone to determine the final hourly demand for each zone. The PROMOD internal hourly load shapes will remain unchanged unless scenario-specific changes are required. When scenario-specific changes are made, the changes will be documented and referenced in any reporting of results.[A]

Demand forecasts are stored in the model as monthly peak values and monthly total energy values for each transmission zone. These forecasts are used to adjust an 8,760-hourly demand profile based on historical data. An 8,760-hourly demand profile for each year is calculated by scaling the base historical profile based on the monthly peak and total energy in the forecast. Demand peak and total energy forecasts can be found from either FERC or the individual ISO. Data that is used for FERC forecasts comes directly from the ISOs/RTOs reports. Data from FERC includes FERC Form 714, Part 3, schedule 2; the data (6) contains load forecast data by ISO, or by transmission zone for some ISOs. Form 714 data is time delayed, with 2017 data posted on July 31, 2018. This data is publicly available on the FERC website.[B]

Data that form ISO/RTO forecasts can come from multiple sources. Load forecast updates by ISO can be found on each ISO website (see Exhibit 2). Midcontinent ISO (MISO) load forecast updates are available from Purdue University's State Utility Forecasting Group. Unless necessary for scenario-specific requirements, the newest version of available data between the FERC 714 and regional load forecasts should be used. The most recent data is used when developing a PROMOD scenario.

[A] PROMOD users should be aware that the load shapes that come with data updates are likely weather normalized and do not represent any single year but are considered typical representations of loads. When new load growth forecasts are input, for instance, higher energy growth with lower peak demand growth, the model will adjust the load shape to the extent the algorithm can, with only extreme changes being unresolvable. Therefore, the load shapes for any scenarios being modeled several years into the future should be inspected to make comparisons with initial data year shapes so it is understood what may be happening to the load shape. The best approach is to check system load factors, energy divided by peak demand times 8760 hours. With low consistent growth in energy and peak demands, one can expect little difference in data year and future year system load factors.

[B] FERC form 714 data can be found at https://www.ferc.gov/docs-filing/forms/form-714/data.asp.

Exhibit 2. Regional load forecasts

Region	Zonal	Link
SPP	No	https://www.spp.org/engineering/transmission-planning/
MISO	No	https://www.purdue.edu/discoverypark/sufg/miso/reports-presentations.php
ISO-NE	No	https://www.iso-ne.com/system-planning/system-plans-studies/celt/
PJM	Yes	http://www.pjm.com/planning/resource-adequacy-planning/load-forecast-dev-process.aspx
NYISO	Yes	https://home.nyiso.com/library/
ERCOT	No	http://www.ercot.com/gridinfo/load/forecast
CAISO	Yes	http://www.energy.ca.gov/2017_energypolicy/
FRCC	No	https://www.frcc.com/Planning/SitePages/Home.aspx
AESO	No	https://www.aeso.ca/grid/forecasting/
BC Hydro	No	https://www.bchydro.com/toolbar/about/planning-for-our-future/irp/current-plan/2013-irp-review.html
Nova Scotia	No	http://oasis.nspower.ca/en/home/oasis/forecasts-and-assessments.aspx

2.4 Fuel Pricing

Monthly fuel price forecasts are provided in the PROMOD model. Coal prices in the model are defined as unit and region specific and are not linked together by central hubs. Coal prices and uranium prices are less subject to change, under normal circumstances. Vendor provided forecasts will be used in the absence of scenario-specific requirements.[C] Natural gas and oil price forecasts are regionally linked to central hub prices. Due to the structure of the price forecasts in the model, changes to the central hub price forecast, such as Henry Hub for natural gas, will propagate to all the regional price forecasts in the model via transportation cost adders. Central hub price changes should be changed in the model to reflect the most recent prices available for natural gas and oil from the sources listed previously. In the absence of scenario-specific requirements, regional price differentials from the hub will remain unchanged.

EIA Short-Term Energy Outlook (STEO) and AEO reports serve as the primary source of fuel price forecasts for the model updates. Unless required for the specific scenario, the reference case is used. The STEO is released once a month and provides monthly natural gas and oil price forecasts for up to two years (7). The AEO is released yearly and provides annual fuel prices to at least 30 years (5). These two sources together provide fuel forecast data to update the model.

When possible, due to increasing reliance on natural gas for power generation, natural gas-electric interdependence should be rigorously modeled using integrated power and natural gas systems models, with natural gas fuel prices set by the natural gas systems models. NETL has the capability to do this through the integrated use of ABB's PROMOD IV® and Deloitte's MarketBuilder North American Gas Model (NAGM).

Other sources for fuel prices from relevant market reports may be used as appropriate depending upon scenario requirements.

[C] Again, if coal and/or uranium prices are altered for a specific scenario, the new prices and rational for change must be clearly documented.

2.5 Emission Pricing

Emissions data in the model is provided by ABB and are tracked regionally and allow for regional $/ton emissions cost adders for sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon dioxide (CO_2), and mercury (Hg). These emissions costs are updated to reflect the appropriate costs associated with the regions and current regulations in the study.

2.6 Transmission System

Complete transmission system information is provided in the ABB model. Eastern Interconnection transmission system updates are sourced from data provided by the Eastern Interconnection Reliability Assessment Group Multiregional Modeling Working Group (8). The data provided by this group for the Eastern Interconnection can be interpreted to provide transmission system changes, or files can be imported into PROMOD to update the transmission system. Transmission system changes for ERCOT and the Western Interconnection can be made using FERC Form 715 Data (9) and by exporting the existing transmission system files from the model, changing them using Siemens PSS/E, and then reimporting the changes back into the model.

3 Unit-Level Modeling

Unit-level modeling updates to a scenario will include updates to existing generating units, the addition of new certain capacity, and the addition of uncertain capacity to ensure each region being modeled meets a NERC reference margin. The guidelines outlined below govern how these unit-level changes should be made to the model.

Generation data updates will include new generation added into the queue and updates to existing generation in the model, including online dates, retirement dates, and operational statuses. Data sources for these updates are described below.

Data for electricity generation are pulled from the following sources in order:

1. ABB Velocity Suite's Energy Velocity database (Velocity Suite) (10) is a searchable database of energy sector market participant and industry dynamics statistics. It contains regularly updated useful information on fuels and power plants that is used to update model information. PROMOD is an ABB product; therefore, data from Velocity Suite also transitions well into PROMOD.
2. S&P Global Market Intelligence (11), formerly SNL Market Intelligence, is another searchable database of information relating to power plants, fuels, and other industry data. The data provided here can be a good source of information when Velocity Suite is lacking, particularly pertaining to financial information.
3. Additional data on existing generator status can be found in the individual Generator Queues for Each Respective ISO
4. Additional sources for generation data can be found in reports from IHS Markit, a market and data analysis group.

3.1 Existing Unit Updates and Certain Additions

Generation unit data of existing units must be updated to reflect the current status of all units in the selected scenario footprint, for the duration of the study. Existing model information must be updated to reflect:

- Announced unit retirement date and unit online date changes
- Extension of unannounced unit retirement dates past the life of the study
- Updated unit heat rates from segmented heat rate values to heat rate curves for relevant unit types
- Updated unit ramp rates[D]
- Updated unit emissions rates reflecting changes to emissions rates and controls
- Updated existing unit statistics that have changed since the last unit update
- Updated renewable generation hourly profiles reflecting regionally appropriate profiles where relevant data is available
- Update demand response, load modifying resources, and other non-energy efficiency load management and response proxy unit on-peak and off-peak energy bid markup values to the higher of $999 per MWh or regional system price cap, unless other bid information is available[E]

New units that have come online, or new certain additions added to the queue since the last model update will be added into the model. New units will be filtered down to units that have been added since the last model update, and which are above a capacity threshold[F], in order to filter out units that should not be added to the model. Unit statistics for these units will be sourced from the unit information where available. When new unit data is not available, new unit statistics will be an average of similar new certain additions, yet to come online.

Heat rates and unit segments are important unit characteristics to review and update as needed. In the event of a new unit, or a change in unit behavior, where appropriate unit characteristics are not available, similar units should be investigated, and the appropriate information pulled from them to create proxy heat rate and capacity segments.

3.2 Uncertain Additions

Once existing generator updates, and certain additions have been added, the model will be run, for the desired study length, in order to calculate the model's planning reserve margin. Planning reserve margin is calculated from the model using reports from the PROMOD report agent. Generation capacity is calculated from the Maximum Dispatchable Capacity weekly report.

[D] Unit ramp rates will be a weighted average of available unit ramp rate information, weighted by reported hours ramping at that rate, due to PROMOD having one ramp rate for all capacity states

[E] PROMOD models demand response, load modifying resources, and other non-energy efficiency load management and response measures as dispatchable generation. Since these resources are normally only called and dispatched during periods of system stress and when other generating resource options are exhausted, a sufficiently large bid markup must be used to reproduce this action.

[F] Unit capacity threshold to be 10MW by default, unless this would make the filtered units greater than 10% of the new unit capacity.

Renewable capacity is calculated by derating the model renewable capacity by the NERC Long-Term Reliability Assessment (LTRA) derate values. Demand response is pulled from the model and subtracted from the Peak Load weekly report.

Forecasted planning reserve margins[G] are calculated on an annual basis using the existing plants, announced retirements and certain additions for the period of a scenario using the following equation:

$$RM = \frac{((\text{Maximum Dispatchable Capacity} + \text{Derated Wind and solar}) - (\text{Peak Load} - \text{Demand Response}))}{(\text{Peak Load} - \text{Demand Response})}$$

If the forecasted capacity is unable to satisfy the NERC reference margin for each ISO, uncertain capacity will be added annually to satisfy the reference margin. Uncertain capacity will be added using the method outlined in the PJM MEMP (1). Uncertain capacity is added as needed based upon the existing certain capacity in the queue for each zone. Generation in the queue for each zone will be summed up by type to determine the percentage by region and unit type. New units will be added to each zone at bus locations that will not disrupt the flow of the transmission zone for that location, usually a central hub for that zone. An example of uncertain additions is shown in Exhibit 3 where certain additions await in the queue. In this example, there are 1,000 MW of new generation in the queue across three regions, with 300 MW of solar, and 250 MW of the solar in Region A. Region A has 25 percent of the new certain solar capacity additions; therefore, Region A will get 25 percent of the required uncertain capacity as solar capacity. Similarly, if Region A has 10 percent of the new certain capacity as coal, then Region A will get 10 percent of the required uncertain capacity as coal capacity.

Exhibit 3. Example of certain and uncertain capacity additions

Unit type	Region A	Region B	Region C
Coal	10%	10%	0%
Natural Gas	0	25%	25%
Solar	25%	0	5%
Regional Total	35%	35%	30%

Critical data of uncertain capacity additions, including heat rates, emissions, fuel costs, operation and maintenance costs, and other relevant statistics will reflect appropriate statistics of similar units for the year the capacity comes online. The unit statistics will be based on available future unit statistics, if provided, otherwise it will be based on an average of yet to come online, similar, certain capacity that exists in the model.

4 Model Scenario Parameters

The following scenario parameters are to be used when running a model scenario, unless otherwise specified in a specific study.

[G] Forecasted planning reserve margins can be found at https://www.nerc.com/pa/RAPA/ri/Pages/PlanningReserveMargin.aspx.

- Model dates should be set as such that each model run segment encompasses a full year
- Model "Resource Development Inclusion Status" should be set to "Planned"
- Model Monte Carlo Simulation will be disabled
- Model Forced Outage Simulation will be disabled

Model dates should be set as such that each model run segment encompasses a full year. This is to insure proper treatment of yearly plant statistics, such as unit maintenance, by the solver. "Resource Development Inclusion Status" under "Scenario Properties" should, in most cases, be set to "Planned." This scenario property directs the inclusion and exclusion of specific generators and transactions from the scenario based upon the "Development Status" set for them under the "Resources – Generators" sub-tab. Resources are included based on a top-to-selected hierarchy from the "Resource Development Inclusion Status," meaning that a status below that which is selected will be excluded from the model. Selection of the "Planned" status, therefore, excludes units listed as "Future" and "Inactive." There are five possible development states for selection: Existing, Under Construction, Planned, Future, and Inactive. The selected development state should follow the NERC resource tier definitions as closely as possible with Tier 1 resources falling under "Existing" or "Under Construction," depending upon their current status. Tier 2 resources should be classified as "Planned" and Tier 3 resources should be classified as "Future." The designation of a unit as "Inactive" should be used in instances where an existing generator is known to be out-of-service with no set return to service date or for units whose current operational status is unknown. Resources listed as "Future" and "Inactive" may not have a complete set of the descriptive metadata necessary for the model to operate and require verification prior to their inclusion.

Model Forced Outage Simulation will also be disabled. Forced outage simulation adds variability in unit results, due to when forced outages occur, and can obscure results from small changes in marginal plants. In order to provide the clearest result for these changes, forced outage simulation will be disabled unless forced outages are a direct change being studied.

5 Model Update Verification

Once each scenario is completely set up, PROMOD can be run, and hourly and monthly results can be reported for each scenario. These results will be used to verify model behavior. This verification is used to check that the system and units being studied are behaving as expected, and that model changes made are properly represented.

High-level verification will be made using monthly results reported out to check the following:

- Verify model-specific changes occurred
    - Did added units dispatch as expected?
    - Did unit additions/ retirement changes occur?
    - Other changes
- Does system demand look as expected (peak load)?
    - Locational marginal prices
    - Generation by unit type

  - Capacity factors by unit type
  - Fuel usages by type

For generator-specific studies, hourly results for the duration of the run will be pulled for specific units that had changes made. Hourly data for the full run will be evaluated, to verify behavior over the length of the run.

- Verification of unit specific changes being properly reflected in appropriate scenarios through hourly and monthly results
  - Unit generation
  - Unit fuel consumption
  - Unit heat rate (calculated value)
  - Other unit specific changes

6 Model Retention

To comply with National Archives and Records Administration (NARA) (13), the Department of Energy (DOE) (14), and NETL Records Disposition guidelines, all final PROMOD model files and results files used in studies should be retained for two years beyond the last publication date of the relevant study, after which time it should be dispositioned according to the NARA disposition guidelines (13).

7 References

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