MEMORANDUM

DATE:	22 AUGUST 2017
SUBJECT:	FORECASTING: ESTIMATING PRICE AND PRICE-RESPONSE

PURPOSE

Energy prices are one of many inputs used by AEMO to develop long term projections of energy consumption and demand.

This document summarises:

1. AEMO's method for forecasting energy prices (AEMO uses a common method for estimating projections of gas and electricity prices[1]).
2. How AEMO uses these projections to develop its forecasts of energy consumption and demand.

PROJECTION OF ENERGY PRICES

Accurate projections require a deep understanding of:

- confidential bilateral agreements between industry participants regarding the cost of energy supply.
- the competitive dynamic between industry participants and end-users.
- the strategic and commercial behaviour of industry participants in respect of the use of, and investment in, gas and electric facilities.
- business portfolio risk as relevant to energy supply by industry participants, and the physical and financial means with which this risk can best be managed.

Since future energy costs can be an important factor in estimating future energy consumption, AEMO sources long term energy price projections from external advisors.

THE ESTIMATION OF ENERGY PRICES

Summary of method

The following summarises how the energy prices used by AEMO in its forecasting are developed:

1. A bottom-up method is used to determine supply-chain costs

   An input-output decomposition of the energy supply system is used to determine cost-based "building-block" components that in total sum to an estimate of final energy prices. Examples of these supply chain costs include wholesale energy costs,

[1] An integrated gas-electricity method is used because gas prices are inputs to electricity prices (via GPG dispatch). The supply-chain cost elements are also similar for determining gas and electricity retail prices: wholesale/transmission/distribution/retail.

network and transmission prices, retail operating costs etc. The economic value of energy is included, represented as a supply-side margin above costs.

2. A top-down method is used to benchmark costs and to and calibrate prices

   Two points of calibration are used to anchor a projection of prices to price levels observed in the market:

   - *Wholesale energy costs –large industrial energy users are surveyed and/or interviewed to determine retail prices that are realised in the market. Large industrial energy users with a base-load consumption profile are assumed to be highly contested in the retail market, implying low retail margins with a low cost to serve when this cost is expressed on a per energy unit basis. On this basis the expected difference between wholesale costs and retail prices is assumed to be small.*
   - *Retail energy prices –published household and small commercial user prices are obtained for each major capital city, based on an assumed load profile and annual quantity. A standard 10% discount on published prices is used as a proxy for available incentives that might be bundled with the price offer. The resultant price is combined with the bottom-up measure of supply-chain costs to estimate a retail margin, where this is treated as the simple residual between estimated costs and observed prices. This retail benchmark is used as an anchor, with annualised price changes estimated from this starting level.*

Detail

The following lists the sequence of modelling steps used in determining energy price projections:

1. Obtain external professional advice on domestic gas supply costs for major load centres and gas power generators. A domestic gas supply-demand balance is used, with prices accounting for the term and details of known supply contracts. Upon expiry of these known contracts, price is assumed to transition to be the maximum of domestic gas supply cost and an assumed LNG export netback cost. Assumed LNG export netback cost is sourced from external professional advisors[2]. Domestic gas supply costs assume an approximate Cournot-Nash game theoretic method in which marginal producers "price-up" to the cost of the next marginal supply source. Prices for major load centres are not marginal supply costs, but rather a "portfolio-average" supply cost based on the source and composition of gas.
2. Domestic gas supply costs are then tested via the survey/interview of Australia's major gas users. Those with flat load profiles and large volumes are assumed to be highly contested with retail prices that proxy the underlying wholesale cost of gas supply. Consistent differences with estimated domestic supply costs are assumed to represent a supplier-margin above cost that is then assumed in supply costs.
3. Updated fuel costs are used to update electricity dispatch modelling, from which fuel use for gas power generation is used to update gas consumption forecasts and dispatch prices are used to update electricity prices. The dispatch modelling

[2] Provided by Core Energy

measures expected market prices, using an approximation of actual bidding behaviour.

4. Supply-chain energy costs are updated to account for known and expected costs as relevant to the retail supply of energy. This uses published transmission and distribution tariffs, assumed wholesale and retail operating costs and a relevant margins. Margins are determined as a residual based on actual published retail prices that are obtained for each market load centre. The result is an estimate of projected retail energy prices.
5. Estimated retail prices are calculated assuming an annual quantity and load profile for major customer segments. These are then presented to industry for validation and review.
6. When large price changes are expected, these retail prices are then used in the demand forecasting models to determine the demand-side response to price changes. The resultant energy consumption forecasts then inform a second-round of this pricing method, for the purpose of understanding how price may act with investment as a dynamic that causes supply and demand to converge to an assumed market equilibrium price and energy outlook.

Validation

AEMO applies a risk-based and stakeholder focussed method to validate its forecasts:

1. All forecasts and forecast inputs are assessed for estimation risk, with this informing a benchmarking and validation method to test estimated results.

   In the case of energy prices the following validation is used:

   a. Professional advice is obtained on international gas prices and the supply-demand balance. In 2016 FGE Singapore was used, with insights tested from advice obtained through Wood Mackenzie.
   b. Professional advice is obtained on the domestic gas supply-demand balance, with domestic gas prices and generation fuel costs estimated on this basis. Core Energy provides this advice to AEMO.
   c. Professional advice on electricity dispatch costs and prices are obtained to test AEMO's own modelling. This advice has been obtained from Jacobs and Marsden Jacobs.
   d. Surveying and/or interviewing of Australia's largest energy users is conducted each six months for the purpose of seeking advice on energy prices.
   e. Professional advice is obtained on the estimation of energy retail prices, with these estimates tested against actual published prices and/or contract prices. This advice has been obtained from Jacobs in the case of electricity, and in the case of Gas, contractors with energy pricing advisory experience are used to validate results.
2. AEMO has developed and implemented a stakeholder engagement plan for the purpose of validating its forecasts:

   a. The Forecasting Reference Group (FRG) was created, comprising forecasting professionals from across Australia, with broad representation from across industry and agencies such as the Australian Energy Regulator.

   b. The FRG provides feedback on AEMO's forecast quality, on methods, assumptions, draft results and on technical forecasting questions when sought. This includes feedback on price forecasts.
3. AEMO publishes its methods and forecasts on the internet, with pricing forecasts available for review.

ESTIMATION OF THE INDUSTRY/CONSUMER RESPONSE TO ENERGY PRICE CHANGES

AEMO estimates the industry/consumer response to energy prices in the following manner:

1. A structural-economic forecasting method is used, based on consumer demand theory and assumptions about structural changes taking place across the energy system, so far that these are relevant to the estimation of future consumption.
2. Prices are assumed to trigger a structural and behavioural response across the energy system:
   a. Structural changes include consumer investments in energy efficient appliances and buildings, investment in energy storage systems and rooftop photovoltaic systems, and changing preferences for electric instead of gas appliances. Within the energy supply system structural changes resultant from energy prices include investment and disinvestment in electric generation technologies, and other technologies in support of the reliability and security of the energy supply system.
   b. Behavioural changes include the changing operating behaviour of assets in the energy supply system, such as generators, as well as changing consumer behaviour regarding their use of gas and electric appliances, or of the way they manage energy consumption (and production/storage) in their dwellings.
3. Observed behaviour in response to price is used to shape the forecast outlook.

   Models are used to prepare limited back-casts that are then compared with actual meter data. This enables the strength of structural dynamics to be compared with an actual benchmark to enable forecast and model tuning. Large load shifts are also tested in electricity supply dispatch models to test the impact of major demand shifts on the supply-side, which can cause price shifts that can mitigate some extent of the original change. Price elasticity of demand estimates are also benchmarked against international reviews.

Detail

Structural price response:

Estimated historic and future energy prices are calculated and used to determine the following structural responses:

- Installed capacity forecasts of rooftop photo-voltaic generation and energy storage.
    - Projected electricity prices are used directly in the model. Prices are used with technology costs to determine investment incentives for new capacity. This model is managed by Jacobs
- Electric vehicle energy consumption forecasts
    - Projected electricity prices are used directly in the model. Prices are used with technology costs to determine investment incentives for new vehicle uptake. This model is managed by Energeia.
- Energy efficiency forecasts for buildings and appliances
    - Price are not used directly in the projections. Projections are based on expected energy efficiency initiatives and technological change. Price is used indirectly to calibrate results. In this way the behavioural and structural response to price is combined with forecasts of energy consumption. These forecasts are back-cast and compared to actuals to test the strength of trends.
- Gas to electric fuel appliance switching
    - Price is indirectly used as an approximate measure of the future incentives for gas to electric appliance switching. Trends are based on observed data for Victoria and projected across the forecast horizon.
- Electricity generation investment and disinvestment
    - Energy prices are used indirectly. Prices changes are used to determine the response of demand, which then is used as an input to an electricity dispatch model that is solved to meet that demand. Prices in this way impact cost and revenue outcomes, and therefore investment and disinvestment in generation.

Behavioural price response:

Estimated historic and future energy prices are calculated and used to determine the following behavioural responses:

- Implied price savings are estimated as an outcome of reductions in energy demand from the following structural changes:
    - Rooftop PV generation –an implied price saving of 100% is combined with a price elasticity of demand assumption of 0.1 to estimate an increase in energy consumption that is consequential to the production of rooftop PV generation [residential only].
    - Energy storage -–an implied price saving of 100% for daytime charging (from rooftop PV), and 50% for overnight charging (from grid supply), is combined with a price elasticity of demand assumption of 0.1 to estimate an increase in

energy consumption that is consequential to the availability of lower cost stored energy [residential only].

    - Energy efficiency –an implied price saving of 100% is combined with a price elasticity of demand assumption of 0.2 to estimate an increase in energy consumption that is consequential to energy consumption savings from energy efficient appliances and buildings [residential only].

- Business sector energy consumption. Energy consumption is reduced in consequence to rising prices (no assumption that consumption increases when prices fall). Price elasticity of demand assumptions are estimated at the low end of a benchmarked range, recognising that expected price increases are exceptionally large, causing a size of impact that affects the supply-side of the market in a way that can mitigate some extent of price increase. The size of price increases also mean price impacts can extend into loads that are less vulnerable to price effects, and therefore that have an assumed smaller price elasticity of demand sensitivity. Modelled elasticities:
    - Manufacturing sector (gas and electricity): Neutral scenario (-0.20), excluding large industrial loads that are known to have secure energy price agreements. Strong scenario (-0.10) and Weak scenario (-0.3). No energy efficiency savings are assumed.
    - Services/other sector (gas and electricity): Neutral scenario (-0.15). Strong scenario (-0.10) and Weak scenario (-0.2). These assumptions combine with energy efficiency savings to determine the total price response.
- Residential sector energy consumption:

  Energy consumption is reduced in consequence to rising prices (no assumption that consumption increases when prices fall). Modelled elasticities:
    - Electricity: Neutral scenario (-0.10), Strong scenario (-0.09) and Weak scenario (-0.12). No energy efficiency savings are assumed for base, cooling, heating and hot water load.
    - Gas: Tariff V residential price elasticities for gas hot water and heating load were estimated for new homes and existing homes separately by analysing Victorian residential metered gas consumption. The overall weighted price elasticity is -0.133 which is consistent with electricity residential price elasticity.