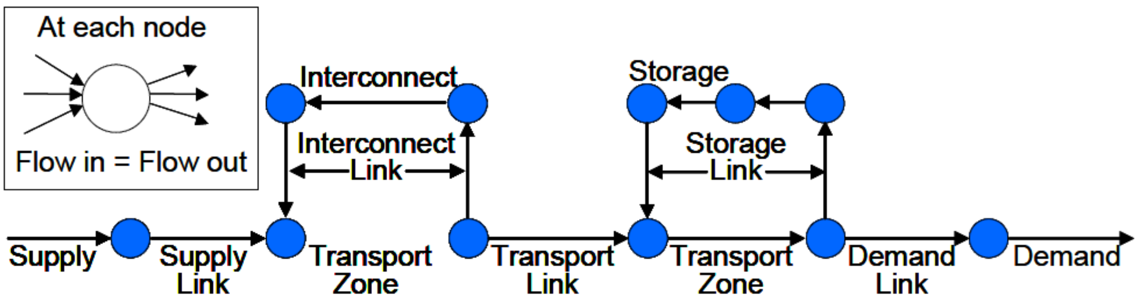
Appendix A GPCM Structure

The GPCM model framework is a node-arc network. Nodes represent production regions and supply basins, pipeline zones, interconnects, storage facilities, delivery points, and either specific large customers or groupings of smaller customers. Arcs represent gas transactions and flows, and are constrained by capacity limitations. Compressors, delivery meters, and receipt meters are rolled up into pipeline zones and arcs connect the pipeline zones to form the regional pipeline networks. Figure A1 is a schematic of the node-arc structure of the GPCM model.

Figure A1. GPCM Node-Arc Structure



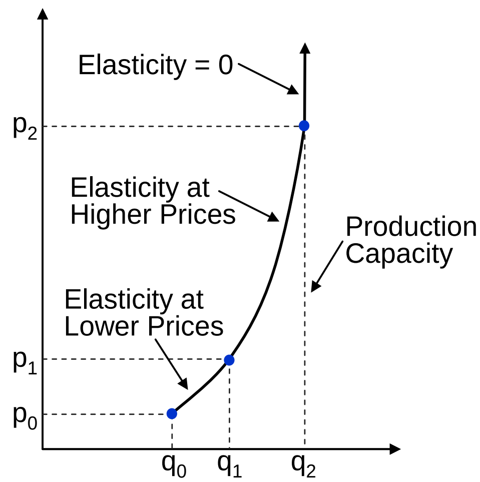
Each arc is defined by a number of parameters including: maximum flow, any required minimum flow, the costs for the arc, and an efficiency to account for compressor fuel and losses. Each supply, demand, or transshipment node is treated as a potential market point where supply and demand must be balanced. Price differentials drive the amount of gas that moves from supply nodes to transshipment nodes and then ultimately to demand nodes. Supply and demand markets are modeled separately and then connected with a model of the pipeline grid. Every supply source is constrained by a maximum and minimum daily flow quantity so that each source has a supply curve that dictates the amount of gas to be supplied at a given netback price.

All major interstate, intrastate, inter-provincial, and cross-border pipelines are included in GPCM. Pipeline zones form the basic building block for modeling each pipeline. Long-haul pipelines, even those with postage stamp rates, are differentiated by zones, enabling flows between contiguous market areas to be defined, capacity constraints to be identified, and price differentials within relevant boundaries to be modeled. Each pipeline's tariff provides the basis for estimating the minimum and maximum transportation prices, as well as relevant fuel retention rates by location, *i.e.*, shrinkage. Pipeline transportation service is prioritized in accord with character of service: all firm transportation is cleared first before any non-firm transportation is cleared in zonal markets. The clearing of non-firm transportation is performed under volumetric rates that range from a high equal to the 100% equivalent load factor rate, including transport commodity and shrinkage, to a low equal to a pipeline's firm transport commodity charge.

GPCM reflects storage dynamics as three distinguishable transaction components: injection, storage and withdrawal. Storage is constrained by total storage capacity and daily injection and withdrawal capacities and is shaped by a monthly schedule with a constant unit cost per period. The ability to model individual storage facilities on a monthly basis allowed consideration of inventory balances, withdrawal and injection rates, and facility constraints. Storage transactions were modeled as bundled under a single rate structure.

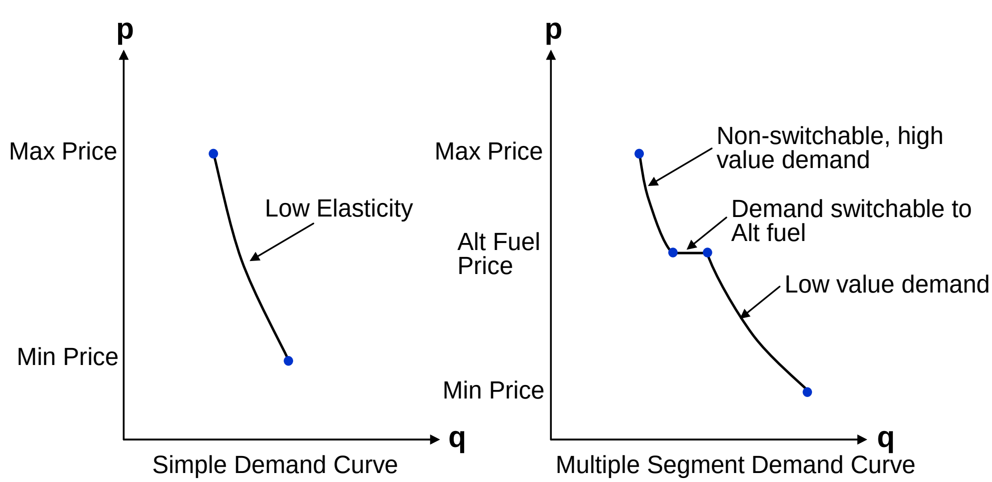
GPCM supply curves relate the amount of gas produced to the price: the higher the price the more gas that will be produced subject to resource and reservoir limitations. The slope of the supply curve determines price elasticity, *i.e*. the change in gas supply that can be obtained for a small change in price. In the customary monthly reporting mode, GPCM supply curves are made up of segments that exhibit high elasticity at lower prices, low elasticity at higher prices, and at some point zero elasticity, where resource and production limits mean that no additional supply can be obtained regardless of price as illustrated in Figure A2.

Figure A2. GPCM Supply Curves



In the monthly reporting mode, GPCM demand curves set the relationship between the price and the amount of gas associated with a customer's preference. GPCM uses a multi-segment demand curve as fuel substitution effects allow certain price-elastic customers to switch to an alternate fuel as illustrated in Figure A3.

Figure A3. GPCM Demand Curves



For purposes of the daily reporting mode used in this study, the demand for both RCI and electric generators are *a priori* inputs on a winter or summer peak day. Therefore price elasticities are of no relevance. The objective function of the LP model is system cost minimization, which determines the economic equilibrium of prices and flows across all the market locations and for all time periods. Model solutions identify congestion points or bottlenecks where price differentials between two points are higher than the transportation costs. In other words, congestion arises when additional gas cannot move from one point to the other.