Natural Gas Infrastructure Adequacy: An Electric System Perspective

PNUCC Study Update
June 13, 2014

Arne Olson, Partner
Nick Schlag, Sr. Consultant
The Western Interstate Energy Board hired E3 and DNV GL to investigate the adequacy of gas infrastructure to meet electric sector needs in the West.

**Phase 1:** Will there be adequate natural gas infrastructure to meet the needs of the electric industry in the West approximately 10 years in the future?

- What demand for natural gas—electric and non-electric—would be expected on the winter and summer peak days?
- Do regional pipelines and storage have sufficient capacity to meet demands?
- Do current market arrangements provide appropriate signals for expansion?

**Phase 2:** Will the gas system have adequate short-term operational flexibility to meet electric industry requirements?

- How large might hourly ramps in the demand for natural gas be?
- Is the gas system physically capable of operating in such a manner as to accommodate the magnitude of these swings?
- Do current market arrangements provide appropriate signals for more variable short-term operations?
E3 and DNV GL have worked closely with the **Technical Advisory Group (TAG)**, a group comprising WIEB staff, industry experts, and representatives of government offices from around the Western Interconnection.

**Technical Advisory Group**
- **Beth Musich**, SoCal Gas & San Diego Gas & Electric
- **Clint Kalich**, Avista Energy
- **Chris Worley**, Colorado Energy Office
- **James Wilde**, Arizona Public Service
- **Jan Caldwell**, Williams Northwest Pipeline
- **Melissa Jones**, California Energy Commission
- **Mia Vu**, Pacific Gas & Electric
- **Peter Larsen**, Lawrence Berkeley National Laboratory
- **Alaine Ginocchio**, Western Interstate Energy Board
- **Steve Ellenbecker**, WIEB
- **Thomas Carr**, WIEB

**Phase 1 report** released March 17; Phase 2 work expected to conclude in June 2014.
E3 has broad experience in electric and natural gas policy, planning and markets:

- Technical assistance to Western Electric Coordinating Council for regional transmission planning
- WECC Energy Imbalance Market Benefits Study
- Flexible capacity modeling for California ISO
- Renewable energy support for California PUC
- Expert testimony on TransCanada mainline tariff issues
+ DNV GL have been providing network analysis software and services since 1970
  - The vast majority of Western U.S. natural gas transmission and distribution companies model with DNV GL software

+ DNV GL have provided consulting services for many of the Western U.S. natural gas companies

+ Some of the Western U.S. DNV GL clients include:
  - Alliance Pipeline
  - Avista
  - Encana
  - Kinder Morgan
  - Northwest Natural
  - Pacific Gas & Electric
  - Puget Sound Energy
  - Questar
  - San Diego Gas & Electric
  - SoCalGas
  - Southwest Gas
  - TransCanada Pipelines Limited
  - Williams Northwest Pipeline
  - Xcel Energy
**Electric System**

- Electric systems are planned to meet a resource adequacy standard
  - E.g. one loss of load event in 10 years
  - Electric sector reliability analysis accounts for generator forced outages—but does not consider possible fuel interruptions
- Transmission expansion is lumpy and difficult
  - Significant visual and other environmental impacts
  - Lack of “exclusive use” due to network impacts

**Gas System**

- Gas transportation infrastructure has its own standards for “adequacy”
  - FERC-regulated pipelines build facilities to meet firm service obligations
  - California sized to meet “cold winter day” planning standards approved by CPUC
- Gas pipeline expansion is incremental and orderly
  - Open season leads to financial commitments
  - California intrastate systems conduct biannual assessments of system capacity
In the past two decades, the vast majority of new investments in generation have been in natural gas technologies, which now represent 42% of installed capacity in the Western Interconnection.

These resources are relied upon to maintain electric reliability.
Electric Sector Gas Consumption in Context

While gas use in the power sector has expanded rapidly during this time, consumption in other sectors has remained relatively stable:

- Over the past fifteen years, the amount of natural gas consumed by the electric sector has nearly doubled.
- The power sector now accounts for between 30-40% of natural gas consumption in the Western Interconnection.
Gas infrastructure in New England is sized to meet winter heating needs of non-power customers, which leaves little capacity available to meet needs of growing electric loads

- Current wholesale power markets provide no incentive/requirement for generators to purchase firm service, and most rely on interruptible
- Regional demand in excess of pipeline capability has led to local gas shortages, resulting in market price “blow-outs”
- During these periods, back-up fuel has helped preserve reliability
Western pipeline systems link production basins with major load centers

Storage facilities located in market areas provide additional load serving capability and flexibility

Pipeline & storage geospatial data obtained from Platts
PHASE 1 INVESTIGATION
Phase 1 Overview

**PHASE 1:**
Will there be sufficient natural gas infrastructure, including storage, to meet the needs of the electric industry in the Western Interconnection approximately ten years in the future?

**Study goals:**
- Identify vulnerabilities where gas infrastructure may not be sufficient to meet electric needs
- Consider implications for long-term resource planning

**Study identifies and explores two vulnerabilities:**
1. Gas generators with interruptible service may not secure gas when capacity is needed by firm shippers
2. During gas infrastructure contingencies, the need to curtail firm gas customers may impact the electric sector
Phase 1 Study Goals

- Study scope is broad, both in geography and in questions it addresses
- E3 and GL have focused on identifying potential challenges without attempting to characterize each one exhaustively
- Study results and conclusions intended to serve as a bridge for more focused, detailed assessment of concerns
Study evaluates gas infrastructure adequacy over a wide range of scenarios, sensitivities, and contingencies.

**Scenarios**
- Base Case
- High Coal Retirements Case
- High Renewables Case
- High Exports Case

**Sensitivities**
- Gas Capacity Sensitivity
- Firm vs. Int Sensitivity

**Contingencies**
- Infrastructure Contingencies
- Extreme Weather Contingencies
The **Base Case** is constructed to reflect a plausible 10-year future for gas consumption in the Western Interconnection considering current policy goals and industry trends.

**Electric sector assumptions:**
- TEPPC 2022 Common Case used as foundation
  - States achieve RPS targets as currently legislated
  - Large portion of electric growth is offset by efficiency
- Several updates reflect evolution of electric industry
  - Retirement of SONGS and several announced coal plants

**Other sector assumptions:**
- Gas consumption grows at rates identified by LDCs in planning documents (e.g. IRPs)
- Implies relatively stable non-power demand in the coming decade
Based on discussions with TAG, the retirement of half of the coal capacity in the Base Case was chosen for the High Coal Retirements Case.

This reduction in coal generating capacity would represent a significant change for the electric sector:

<table>
<thead>
<tr>
<th>Installed Coal Generation Capacity (MW)</th>
<th>Existing (2010)</th>
<th>PC1 Common Case (2022)</th>
<th>PC6 Coal Replacement Case</th>
<th>Base Case</th>
<th>High Coal Retirements Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>MW</td>
<td>39,518</td>
<td>35,182</td>
<td>29,812</td>
<td>33,568</td>
<td>16,543</td>
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<tr>
<td>TEPPC Study Cases (2022)</td>
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<tr>
<td>Gas-Electric Study Cases (2022)</td>
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</table>
High Renewables Case

- State-specific RPS targets were adjusted upwards by increments determined by E3 and TAG.

- Increased targets resulted in a need for approximately 50 TWh of additional renewable generation.

- WECC-wide RPS is approximately 27%.
  - 18% in Base Case.

- Additional renewable generation added to meet gaps was primarily wind & solar.

Percent of Retail Loads Served by Renewables

WECC-Wide Renewable Generation
Overview of Analytical Steps

**Step 1:** Establish regional estimate of “load carrying capability”

RESULT: Total infrastructure capability

**Step 2:** Forecast demands for natural gas under winter conditions

RESULT: Firm/interruptible electric/end use loads

**Step 3:** Determine how much capacity will be used by firm shippers

RESULT: Capacity available for interruptible shippers

**Step 4:** Determine whether interruptible loads can be met with available capacity

RESULT: Possible curtailment of gas service to electric generators

**Step 5:** Translate curtailments to electric terms and compare to operational mitigation strategies
Includes loads served by Williams Northwest Pipeline in the I-5 Corridor

Recent PNUCC/NWGA studies have closely monitored the balance between capacity and demand in this region

E3’s analysis indicates some risk of curtailment to gas generators under extreme winter weather conditions (1-in-35) in 2022

- Risk mitigated by backup fuel capability
Pacific Northwest - East

- Includes loads served by multiple pipelines:
  - Williams Northwest east of Cascades
  - TransCanada GTN
  - Ruby Pipeline
- Recent development of Ruby pipeline has changed the balance of gas infrastructure in this region
- Capacity appears adequate to meet needs of electric sector in Base Case

### Natural Gas Infrastructure Capacity Balance under Winter Loading Conditions (MMcf/d)

<table>
<thead>
<tr>
<th></th>
<th>Winter Weather Conditions</th>
<th>1-in-2</th>
<th>1-in-10</th>
<th>1-in-35</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load Carrying Capability</td>
<td></td>
<td>5,192</td>
<td>5,192</td>
<td>5,192</td>
</tr>
<tr>
<td>Firm Demands</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Downstream End Use</td>
<td></td>
<td>2,600</td>
<td>2,600</td>
<td>2,600</td>
</tr>
<tr>
<td>Downstream Electricity</td>
<td></td>
<td>1,077</td>
<td>1,295</td>
<td>1,430</td>
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<tr>
<td>Electric</td>
<td></td>
<td>302</td>
<td>302</td>
<td>302</td>
</tr>
<tr>
<td>Capacity Remaining for Interruptible</td>
<td></td>
<td>1,214</td>
<td>995</td>
<td>860</td>
</tr>
<tr>
<td>Interruptible Demands</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>End Use</td>
<td></td>
<td>71</td>
<td>77</td>
<td>81</td>
</tr>
<tr>
<td>Electricity</td>
<td></td>
<td>303</td>
<td>488</td>
<td>613</td>
</tr>
<tr>
<td>Capacity Shortfall</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Electric Sector Share of Shortfall</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

### Service of Electric Sector Natural Gas Demand under Winter Weather Conditions (MMcf/d)

- [Bar chart showing service levels](chart)

### Regional Gas Generation under Winter Loading Conditions (MW-days)

<table>
<thead>
<tr>
<th></th>
<th>Winter Weather Conditions</th>
<th>1-in-2</th>
<th>1-in-10</th>
<th>1-in-35</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Generation Summary</td>
<td></td>
<td>3,504</td>
<td>4,372</td>
<td>4,855</td>
</tr>
<tr>
<td>Curtailed</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Available Mitigation Measures</td>
<td></td>
<td>334</td>
<td>334</td>
<td>334</td>
</tr>
<tr>
<td>Backup Fuel</td>
<td></td>
<td>334</td>
<td>334</td>
<td>334</td>
</tr>
<tr>
<td>Imports</td>
<td></td>
<td>7,137</td>
<td>7,124</td>
<td>6,950</td>
</tr>
<tr>
<td>Net Capacity Shortfall after Mitigation</td>
<td></td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
1. Natural gas and electric industries are deeply linked

2. In Base Case, gas infrastructure is generally be adequate to meet the regional needs of the electric sector except under the most extreme winter weather conditions

3. Gas generation without firm service may be subject to interruption during periods of high gas demand

4. The regions of the Western Interconnection are highly interdependent in their reliance on natural gas transportation and generation infrastructure

5. Regional coordination can play a key role in responding to gas generation curtailments during extreme weather

6. Extreme events that affect multiple regions simultaneously could cause loss of electric load

7. The loss of critical gas infrastructure presents a plausible risk not traditionally considered in electric sector reliability planning

8. Continued growth of the West’s natural gas generation fleet will require expansion of natural gas infrastructure

9. Impacts of new large loads on the adequacy of gas transportation infrastructure depends on the extent to which those loads rely upon incremental expansions or existing pipelines
Conclusions recognize two vulnerabilities that could limit the availability of gas generators during peak periods:

- Reliance on interruptible service
- Loss of critical gas infrastructure

Traditional reliability planning uses a stochastic approach to determine the appropriate reserve margin.

Incorporating these vulnerabilities into a stochastic framework would provide useful quantitative info to resource planners:

- How “firm” is a resource with interruptible service?
- How does the potential for infrastructure contingencies affect loss-of-load probability?

### Stochastic Variables in Reliability Modeling

<table>
<thead>
<tr>
<th>Variable</th>
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<tbody>
<tr>
<td>Electric Load</td>
</tr>
<tr>
<td>Generation Forced Outages (non-fuel related)</td>
</tr>
<tr>
<td>Transmission Outages</td>
</tr>
<tr>
<td>Renewable Output</td>
</tr>
<tr>
<td>Hydro Availability</td>
</tr>
<tr>
<td>Import Availability</td>
</tr>
<tr>
<td>Curtailment of Interruptible Gas Generators</td>
</tr>
<tr>
<td>Gas Infrastructure Outage (impacts on gas generators)</td>
</tr>
</tbody>
</table>
The Western Interconnection’s rich transmission network is a source of resilience during strained conditions.

Results of production simulation indicate available capacity on key transmission paths during times of potential constraints on gas infrastructure.
The impacts of new large loads on the adequacy of gas transportation infrastructure will depend on the extent to which those loads rely upon incremental expansions or existing pipelines.

- New firm loads that trigger expansion would have limited impact on the electric sector.
- New interruptible loads could limit availability of capacity for the electric sector.

**NOTE:** This analysis focuses only on the adequacy of gas infrastructure—not on the adequacy of supply.

- New large export volumes will also increase competition for gas in the Western Interconnection.
PHASE 2 ANALYSIS
Phase 2 Overview

**PHASE 2:**
Will the gas system have adequate short-term operational flexibility to meet increased volatility in hourly electric industry natural gas demand due to higher penetration of variable renewable resources in the Western Interconnection?

Phase 2 investigation addresses multiple questions:

- How will increased variability in demand from electric generators impact interactions between pipeline systems in the Western Interconnect?
- During which times of year are pipelines most likely to encounter challenges related to variability of demand?
- Will the intraday variability of electric sector needs exceed the physical capability of pipeline systems to accommodate changes in demand within the operating day?
- Does the forecast error and uncertainty of renewable generation pose a potential challenge for the electric sector due its impact on scheduling and nominations of natural gas?
Pipeline Participation

+ E3 and GL have met individually with members of the Pipeline Working Group (PWG) to discuss concerns related to the variability of power sector demands and to inform Phase 2 work plan

+ Meetings are ongoing and will continue to facilitate Phase 2 analysis

+ Discussions with individual companies have helped shape focus of Phase 2

<table>
<thead>
<tr>
<th>Participating Companies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kern River</td>
</tr>
<tr>
<td>Kinder Morgan</td>
</tr>
<tr>
<td>Northwest Natural</td>
</tr>
<tr>
<td>Pacific Gas &amp; Electric</td>
</tr>
<tr>
<td>Questar</td>
</tr>
<tr>
<td>Southern California Gas</td>
</tr>
<tr>
<td>Southwest Gas Co</td>
</tr>
<tr>
<td>TransCanada</td>
</tr>
<tr>
<td>Transwestern</td>
</tr>
<tr>
<td>Williams Northwest</td>
</tr>
</tbody>
</table>
Gas Generation at High Renewable Penetrations

As Western states pursue aggressive renewable policy goals, higher penetrations of wind and solar will transform the role of gas generation

- Intraday variability of gas demand in the power sector will change as plants are used for ramping to accommodate renewables
- Shift in investment to fast-ramping and quick-start units will place new demands on gas pipelines

Growing need for flexibility starting 2015

- Significant change starting in 2015
- Increased ramp
- Potential over-generation
Managing Variability

+ Basic services offered by pipelines allow consumers to use gas on a “ratable” basis – constant throughout the day

+ Two operational tools allow gas infrastructure to meet variable demands throughout the day
  - Management of line pack
  - Withdrawals from underground storage

Figure Source:
Kinder Morgan presentation on Capacity Reservation Factors
Choosing Geographic Scope

+ What geographic scope is appropriate for case studies of electric sector variability?

**Segment**
(e.g. Williams Northwest Pipeline in the I-5 Corridor)

**Regional**
(e.g. Pacific Northwest as a whole)

**System**
(e.g. GTN pipeline)

+ Because pipelines plan and operate to deliver gas on a ratable basis to interconnects, the impacts of variability are confined to individual pipeline systems
Choosing Seasonal Scope

- Case study analyses focus on winter peak conditions as the most challenging periods for managing variability.

- Two main factors contribute to the choice of high load conditions for study:
  
  1. Aggregate demand is most variable during winter peak due to heating end uses.

  2. Tolerance for swings in linepack is lowest in winter due to higher levels of throughput.

There is a direct physical tradeoff between throughput and flexibility: at higher levels of throughput pipelines can tolerate less variation in linepack (figure derived from simple hydraulic model).
Case Studies in the Pacific Northwest

+ **Williams Northwest in I-5 Corridor** *(draft results)*

  - Transient simulation developed explicitly in support of western gas-electric study
  - Model used to evaluate flexibility in periods of high winter load during a large ramp in wind generation

+ **TransCanada GTN** *(modeling ongoing)*

  - Transient simulation in progress
  - Model will test flexibility on both an abnormal high flow and abnormal low flow day
Case studies investigate capability of gas infrastructure to serve variable intraday demands:

- **Electric sector** profiles on winter days with high ramping needs chosen from GridView production simulation analysis
  - “Base Case” derived from TEPPC 2022 Common Case
  - “High Renewables Case” includes additional wind and solar resources throughout the WECC
- **Other end use demand** profiles provided by pipelines based on historical/forecast periods of high demand
Wind-heavy regions may experience large upward ramps in gas use.

Large downward ramp in wind generation is focus of analysis.
Variability of electric sector limited in relation to other end uses
Williams Northwest developed a transient simulation model by replicating operations for December 3-7, 2013

- Period of high overall demand; gas generators running at high capacity factors throughout the period

Comparisons are drawn between the simulation of actual historical operations (“2013 Model”) and the 2022 Base Case snapshot (“2022 Base Case”)
2022 Base Case demand is met with limited deviation from historical levels of linepack.

Deliveries

**System Linepack**

Small differences in linepack from historical operations

Receipts - Sumas

Storage Withdrawals - Jackson Prairie

Small differences in Sumas receipts

JP absorbs most variation from historical operations
Impacts of Imbalances

+ With receipts and deliveries in balance from one day to the next, pipeline recovers linepack over the course of the day.

+ A persistent deficiency of receipts (i.e. demand higher than expected) may cause erosion of linepack and operational challenges.

+ As penetration of wind generation in the Pacific Northwest grows, forecasting needs of gas generators may become more challenging on a day-ahead basis.
Accuracy of wind power forecasts will affect the ability of operators to forecast the needs of gas generators.

- System operators schedule natural gas plants based on forecasted wind output.
- Natural gas plants nominate and schedule gas supplies based on these directions.

Wind forecast errors, defined as the forecast value minus actual wind power, may impact gas consumption in the following way:

- **Positive errors** (over-forecast) may lead to gas generators burning more gas than they nominated.
- **Negative errors** (under-forecast) may lead to gas generators burning less gas than they nominated.
Gas Nomination Cycle and Wind Power Forecasting

Timely nomination deadline

What is the average wind forecast error during the gas day, and how does that affect gas generation?
Comparing Wind Forecast Errors at Different Time Scales

+ The 24-hr average wind forecast error drives the amount of additional natural gas needed over the gas day

+ These 24-hr wind forecast errors have less variation from the average
Fitting Distribution to Observed Forecast Errors

Wind over-forecasts from fitted distribution:

- **97.5th percentile**: 14.1% installed capacity
- **99th percentile**: 18.2% installed capacity
E3 applied the 97.5\textsuperscript{th} and 99\textsuperscript{th} percentiles from the fitted distribution to projected wind capacities across the PNW

- Note: extending BPA data for the entire region

Base Case forecast errors are similar to present-day BPA forecast errors when they normalized by the amount of installed gas capacity

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Installed Wind Capacity (MW)</th>
<th>Forecast Error 97.5\textsuperscript{th} Percentile (MW-d)</th>
<th>Forecast Error 99\textsuperscript{th} Percentile (MW-d)</th>
<th>Installed Gas Capacity (MW)</th>
<th>Forecast Error as % Gas Capacity, 97.5\textsuperscript{th} Percentile</th>
<th>Forecast Error as % Gas Capacity, 99\textsuperscript{th} Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPA Existing (2014)</td>
<td>4,500</td>
<td>637</td>
<td>821</td>
<td>3,500</td>
<td>18.2%</td>
<td>23.5%</td>
</tr>
<tr>
<td>PNW Base Case (2022)</td>
<td>12,099</td>
<td>1,712</td>
<td>2,208</td>
<td>9,654</td>
<td>17.7%</td>
<td>22.9%</td>
</tr>
<tr>
<td>PNW High RPS Case (2022)</td>
<td>19,736</td>
<td>2,792</td>
<td>3,601</td>
<td>9,654</td>
<td>28.9%</td>
<td>37.3%</td>
</tr>
</tbody>
</table>
Analyses of multiple regions support similar conclusions:

1. Physical infrastructure is generally equipped to handle ramps in demand provided shippers maintain balance between receipts and deliveries.

2. Imbalances in receipts and deliveries – potentially caused by forecasting challenges related to renewables – could create operational challenges for pipelines.

Phase 2 report is currently underway, E3 and GL working to incorporate modeling results of case studies.
Thank You!

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