Natural Gas Infrastructure Adequacy: An Electric System Perspective

State Provincial Steering Committee
Phase 2 Study Results
August 13, 2014

Arne Olson, Partner
Nick Schlag, Sr. Consultant
Gabe Kwok, Consultant
Zach Ming, Sr. Associate

Mark Bolze, DNV GL
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?
**Scenarios Considered**

+ **Base case**
  - Existing trends through 2024

+ **High coal retirements**
  - 50% of remaining coal plants retired

+ **High renewables**
  - 27% RPS in WECC

+ **High export sensitivity**
  - 2.0 MMcf/d in SW, 1.5 MMcf/d in NW
About the Study

- Study sponsored by the Western Interstate Energy Board and supported by the DOE’s National Energy Technology Laboratory under Award Number DE-OE0000422.

- E3 and DNV GL have worked closely with the Technical Advisory Group (TAG), comprising WIEB staff, industry experts, and government officials 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
- Mark Westoff, Kinder Morgan
- 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 report** released July 30, 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
Pipeline Participation

E3 and GL met individually with members of the Pipeline Working Group (PWG) throughout Phase 2 to discuss concerns related to the variability of power sector demands.

A number of PWG members voluntarily contributed modeling resources and additional time to inform the study’s findings:

- Kinder Morgan
- Northwest Pipeline
- PG&E
- SoCalGas
- TransCanada

Pipeline Working Group

- Kern River Gas Transmission Co.
- Kinder Morgan
- Northwest Natural
- Northwest Pipeline
- Pacific Gas & Electric
- Southern California Gas Co.
- Southwest Gas Co.
- TransCanada Corp.
- Transwestern Pipeline Co.
At the project’s onset, Lawrence-Berkeley National Lab (LBNL) agreed to conduct an independent review of the study process and methods.

Results of independent review are published in a separate document from the report.
1. Review of Phase 1 findings
2. Overview of Phase 2
3. Scope development
4. Case studies
5. Conclusions & next steps
PHASE 1 REVIEW
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 1 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
Phase 1 Key Findings

+ Western gas infrastructure will generally be adequate to meet the needs of the electric sector except under the most extreme winter weather conditions.

+ Regions are linked and extreme regional weather events can cause loss of electric load.

+ Gas generation that does not contract for firm transportation service may be subject to interruption.

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

---

**Total Gas Consumption (Tcf/yr)**

**WECC Annual Consumption (Tcf/yr)**

**Historical**

**Additional Demand, Coal Retirements**

**Base Case Electric**

**End Use**

![Graph showing total gas consumption](chart.png)
Implications of Analysis for Electric Resource Planning

Electric systems are typically planned to meet a reliability-based standard (e.g. one loss of load event in ten years).

Stochastic approach to determines reserve margin needed to meet this threshold given the low probabilities of extreme events.

This study identifies two material vulnerabilities to the power sector that are not traditionally incorporated into this framework.

Stochastic Variables in Reliability Modeling

- Electric Load
- Generation Forced Outages (non-fuel related)
- Transmission Outages
- Renewable Output
- Hydro Availability
- Import Availability

Additional vulnerabilities

- Curtailment of Interruptible Gas Generators
- Gas Infrastructure Outage (impacts on gas generators)
PHASE 2 OVERVIEW
Phase 2 Questions

**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?
As Western states pursue 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

Will the gas system have adequate short-term operational flexibility to meet increasingly variable power sector demands?
Basic services offered by pipelines entitle consumers to use gas on a “ratable” basis – constant throughout the day.

However, in daily operations, demand for natural gas among many end users is not “ratable”:

- Residential use peaks in mornings and evenings with heating loads
- Commercial use often directly linked to building schedules
- Peaking power plants require large amounts of fuel in short periods

Two operational tools allow gas infrastructure to meet variable demands throughout the day:

1. Management of linepack
2. Withdrawals from underground storage
“Linepack” refers to the volume of gas that is stored in the pipeline system.

Management of fluctuations in linepack allows a system to balance small differences in receipts and deliveries over short time scales.

Figure Source: Kinder Morgan presentation on Capacity Reservation Factors
The ability of a pipeline to tolerate fluctuations in linepack is directly linked to its level of throughput: size of “flexible range” narrows with increasing throughput.

a) When a pipeline serves a demand equal to its design capacity, it cannot tolerate any fluctuation in throughput.

b) When it is operated to meet demand that is lower than its capacity, the system may carry a higher level of linepack; or

c) At that same level of lower demand, the pipeline may carry a lower level of throughput.
On a number of Western systems, underground storage located in the market area contributes to the system’s flexibility. By allowing for variable rates of withdrawal, storage can be used to balance variable demands and reduce the need for fluctuations in linepack.

Two applications of storage:

- **Balancing:** storage inventory owned by pipeline used to manage linepack
- **Nominated:** storage inventory owned by or contracted to shippers that can be withdrawn at a variable rate through nominations (often with “no notice”)
One of the important characteristics of gas systems recognized in Phase 1 is the link between firm contracting and physical capacity.

A gas user’s choice of service also has direct bearing on a gas system’s flexibility:

- In order to serve a variable profile of deliveries, a pipeline must have some idle capacity to absorb fluctuations in linepack.

Two conditions must be met for a system to tolerate linepack fluctuations:

1. Physical pipeline capacity must exist.
2. It must not be by another shipper.
In order to receive gas service, a shipper must submit a nomination to the pipeline, which indicates a volume of gas to be transported from a point of receipt to delivery.

Pipelines rely on nominations to schedule flows and prepare systems to meet deliveries.

<table>
<thead>
<tr>
<th>Cycle</th>
<th>Nomination Due</th>
<th>Confirmation</th>
<th>Gas Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timely</td>
<td>9:30 AM (day ahead)</td>
<td>2:30 PM (day ahead)</td>
<td>7:00 AM</td>
</tr>
<tr>
<td>Evening</td>
<td>4:00 PM (day ahead)</td>
<td>8:00 PM (day ahead)</td>
<td>7:00 AM</td>
</tr>
<tr>
<td>Intraday 1</td>
<td>8:00 AM (day of)</td>
<td>12:00 PM (day of)</td>
<td>3:00 PM</td>
</tr>
<tr>
<td>Intraday 2</td>
<td>3:00 PM (day of)</td>
<td>7:00 PM (day of)</td>
<td>7:00 PM</td>
</tr>
</tbody>
</table>

In FERC’s ongoing gas-electric coordination docket, stakeholders have identified a number of issues with current timing and rules regarding nominations.

While study is not focused on nominations and scheduling process directly, the conventions established therein directly relate to the flexibility of pipeline systems.
SCOPE DEVELOPMENT
Case Study Approach

Phase 2 analysis relies on “Case Studies”: targeted assessments of flexibility issues under specific conditions within a limited geographic scope.

To design case studies appropriately, several questions were investigated in the development process:

- During which times of the year are pipelines most likely to encounter challenges related to variability of demand?
- What is the appropriate geographic scope for a case study of flexibility?

Pipeline & storage geospatial data obtained from Platts.
During which times of the year are pipelines most likely to encounter challenges related to variability of demand?

Whereas demand for natural gas exhibits strong seasonal trends, linepack remains relatively stable throughout the year.

Analysis focuses on winter peak periods for two reasons:

1. Flexibility of linepack is most constrained during peak demand periods due to the direct tradeoff between throughput and flexibility.

2. Expected intraday variability of demand during the winter peak is generally expected to be largest, as both the electric sector and the end use sectors experience large intraday ramps.

Daily Historical Linepack by System

(a) El Paso Natural Gas Company

(b) Pacific Gas & Electric Company

(c) Northwest Pipeline (in I-5 Corridor)
Variability at a Regional Scale

What is the appropriate geographic scope for a case study of flexibility?

Regional: multiple pipeline systems serving a single region
System: a single pipeline system as a whole
Segment: a small portion of a pipeline system

One of the key conventions of the gas industry is that gas systems plan and schedule flows on a ratable basis

- This implies that each pipeline system is responsible for managing the variability of the demands it serves

Variability is managed at a system level, not at a regional level
Six case studies were evaluated:

1. **Southern California**: Southern California Gas/San Diego Gas & Electric system
2. **Northern California**: Pacific Gas & Electric system
3. **Desert Southwest**: “Power Plant Alley” segment of El Paso Natural Gas Company Southern Mainline
4. **Pacific Northwest, West of Cascades**: I-5 Corridor of Northwest Pipeline in Western Washington
5. **Pacific Northwest, East of Cascades**: TransCanada GTN system
6. **Colorado Front Range**: Colorado Interstate Gas system in Colorado

Pipeline geospatial data obtained from Platts; power plant locations from EIA
CASE STUDIES
Case studies focus on gas systems during winter periods of high demand and high variability (1-5 days)

Input data for case studies is developed in three steps:

a. Use production simulation results to identify winter periods with high “net load” variability

b. Assess utilization of gas generation to meet net load variability during this period

c. Layer gas demand on top of profiles of assumed deliveries to non-electric users
Summary of Inputs and Assumptions

Profiles for electric gas demand derived from production simulation analysis from Phase 1:

- **Base Case**: based on TEPPC 2022 Common Case
- **High Renewables Case**: includes additional renewable generation

Profiles for deliveries to non-electric users based on historical and/or forecast data provided by participating pipelines
Reference Assumptions:
Southern California

+ Winter day with largest evening net load ramp in California identified in production simulation modeling

+ Corresponding dispatch of gas generators served by SoCalGas extracted from production simulation results

+ Hourly demand from generators on the SoCalGas system added to forecast of 1-in-10 peak among non-electric end uses
Reference Assumptions: Pacific Northwest, West of Cascades

+ Winter period with large variability in wind generation in the PNW identified (five days)

+ Corresponding dispatch of gas generators located in I-5 Corridor extracted from production simulation results, showing large upward ramp

+ Hourly demand from gas generators added to profile of historical demands in I-5 Corridor from December 3-7, 2013 (highest historical demand)
Scope of Case Studies

- In each case study, the gas system is evaluated in its ability to meet demand under ‘Reference Assumptions’
- Where possible, sensitivity analysis on key inputs is conducted

<table>
<thead>
<tr>
<th></th>
<th>Southern California</th>
<th>Northern California</th>
<th>Desert</th>
<th>Southwest</th>
<th>Pacific Northwest, West of Cascades</th>
<th>Pacific Northwest, East of Cascades</th>
<th>Colorado Front Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference Assumptions</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sensitivity: Increased Electric Sector Ramp</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sensitivity: Supply-Demand Imbalance</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Sensitivity: Level of Non-Electric Demand</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
A **hydraulic model** simulates the operations of components of gas infrastructure as gas flows between the points of receipt and delivery.

Hydraulic models may either be run in steady state or in transient mode:

- **Steady state**: receipts and deliveries are static, system is in equilibrium
- **Transient (focus of Phase 2)**: receipts and deliveries reflect changing conditions, system operations are dynamic in response to changes
Criteria for Evaluation

Fundamental question addressed by the hydraulic model:

*Can a gas system deliver the necessary quantity of gas to meet all demands at sufficient pressure while operating within its physical limits?*

The “success” of a transient hydraulic simulation is measured by a number of criteria:

1. All gas is delivered to loads
2. All facilities remain within stated capacities
3. Minimum delivery pressure obligations are met
4. Linepack is recovered over the course of the simulation
CONCLUSIONS
1. Under the conditions examined in this study, meeting the variable gas demands needed to integrate high penetrations renewables is technically feasible.

+ This study describes the two primary tools used by pipelines to meet variable demands:
  1. Linepack management
  2. Storage withdrawals and injections

+ Most importantly, these characteristics suggest that meeting variable loads needed to integrate renewables is technically feasible.
2. The addition of renewable generation to an electric system reduces the overall level of gas demand while increasing its variability.

- Notwithstanding increased variability, reduced natural gas demand due to renewables provide opportunities to recover linepack and prepare system to meet ramps.

- In many cases, the impact of renewable generation on natural gas demand are relatively small compared to total demand during peak periods.
  - Impact of solar generation on El Paso hourly demand and line pressure is limited.

---

**Results of El Paso Simulations**

(a) Total deliveries (to Phoenix, Power Plant Alley, Wenden)

(b) Pressure at Casa Grande (upstream of Power Plant Alley)

(c) Pressure at Wenden (downstream of Power Plant Alley)
3. Imbalances between gas deliveries and receipts to gas systems can cause operational challenges

- Gas system operators rely on nominations of receipts and deliveries from shippers to schedule gas flows
- When schedules do not align with actual needs, imbalances result
- To a certain extent, linepack management and balancing storage may absorb these variations, but larger imbalances may create operational challenges

Results of SoCalGas Hydraulic Analysis of High Renewables Case

(a) SoCalGas system receipts and deliveries

(b) Pressure at San Diego

Note time scale begins and ends at 6AM
4. The intermittency and unpredictability of renewable generation may increase the frequency and magnitude of imbalances on pipeline systems

- The forecast errors of wind and solar resources contribute to the uncertainty of gas generators in their need for fuel to support operations.
- Those errors translate to inaccuracies in nominations submitted for transportation.
- Further work is needed to understand the magnitude of this impact for gas system operations.

Results of Xcel Energy 2011 Wind Integration Study

- **Gas storage ($0.17/MWh):** costs of gas storage needed to balance inaccuracies in gas nominations.
- **Regulation ($0.21/MWh):** costs of holding additional regulation reserves to balance intra-hour variability of wind.
- **System operations ($3.71/MWh):** costs resulting from suboptimal operations of electric resources due to wind power uncertainty.

Source: Xcel 2011 Wind Integration Study
5. Transportation services tailored to meeting variable demands may facilitate renewable integration

+ Standard services offered by pipelines entitle a shipper to receive and deliver gas on a ratable basis

+ Creatively structured services could allow generators to secure the fuel they need and also provide the appropriate investment signal to pipelines when necessary to trigger efficient expansion of gas infrastructure

**El Paso Natural Gas Co. Hourly Firm Service (Schedule FT-H)**

- Shipper contracts for service according to a variety of specified hourly profiles
- Shipper pays a “Capacity Premium” associated with the fixed costs of the capacity needed for useable linepack
- When shipper nominates daily volumes, capacity needed for linepack management is also reserved
6. Gas generation with firm contracts may not receive transportation service if it does not nominate appropriate volumes to match its needs

+ Reminder of Ph1 conclusion: “Gas generation that does not contract for firm transportation service may be subject to interruption during times of high gas demand”

+ Merely holding firm service does not sufficient to guarantee access to natural gas on demand:
  - Pipelines may not be capable of meeting un-nominated demands
  - Capacity associated with a firm contract may be allocated to other shippers if not scheduled in the Timely (first) cycle
7. Gas systems in the Western Interconnection depend on their neighbors to meet scheduled obligations to ensure reliable operations

- Reminder of Ph1 conclusion: “The regions of the Western Interconnection are highly interdependent in their reliance on natural gas transportation and generation infrastructure”

- This study assumes that pipelines uphold their obligations to neighboring systems to deliver gas on a ratable basis, implying that each system manages its own variability

- If one pipeline system is unable to deliver scheduled flows to interconnects, impacts may spread
  - Not a concern specific to renewable integration
Next Steps

- Investigate impacts of renewable forecast error on gas nominations and scheduling
- Conduct detailed regional and local studies of gas infrastructure under higher renewable penetrations
- Continue to monitor regional balances between demand for natural gas and available capacity of pipeline systems
- Continue to explore refinements to the nominations and scheduling process to facilitate gas system operations
- Support ongoing efforts to establish reliable communications between gas and electric system operators
- Explore transportation service options that might facilitate efficient and reliable integration of renewables
Thank You!

Energy and Environmental Economics, Inc. (E3)
101 Montgomery Street, Suite 1600
San Francisco, CA 94104
Tel 415-391-5100
Web http://www.ethree.com

Arne Olson arne@ethree.com
Nick Schlag nick@ethree.com