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February 17, 2022

Institute for Catastrophic Loss Reduction
Suite 210, 20 Richmond Street East
Toronto, ON M5C 2R9

Attention: Mr. Glenn McGillivray

Dear Mr. McGillvray:

Re: FortisBC Energy Inc. (FEI)

Project No. 1599211

Application for a Certificate of Public Convenience and Necessity (CPCN) for Approval of the Advanced Metering Infrastructure (AMI) Project (Application)

Response to the Institute for Catastrophic Loss Reduction (ICLR) Information Request (IR) No. 1

On May 5, 2021, FEI filed the Application referenced above. In accordance with the regulatory timetable as amended in BCUC Order G-389-21 for the review of the Application, FEI respectfully submits the attached response to ICLR IR No. 1.

For clarity, FEI confirms the position expressed in Exhibits B-10, B-11 and B-12 (including with reference to Exhibit A-15) regarding the process and evidentiary impact of matters stated in preambles to information requests. However, FEI has again provided responsive information in the enclosed to enable a transparent and fulsome adjudication of the Application.

If further information is required, please contact the undersigned.

Sincerely,

FORTISBC INC.

Original signed:

Diane Roy

Attachments

cc (email only): Commission Secretary
Registered Parties

1.1 How will FortisBC detect or know an earthquake has occurred?

Response:

FEI receives notifications of seismic events through a variety of sources, including National Resources Canada (NRCAN), Emergency Management BC (EMBC) and the United States Geological Survey (USGS), and is looking into other systems to augment current capabilities. Following a seismic event or tsunami warning, emergency management personnel are immediately notified by Emergency Management BC via simultaneous automated email, phone calls, and text messages of the location and magnitude.

FEI supported early testing in partnership with Ocean Networks Canada (ONC) to develop early warning information that could be received by FEI staff 24 hours a day. This system is currently under development and FEI anticipates establishing automated reporting and notification from the early warning system.

1.2 How long will it take FortisBC to know an earthquake has occurred?

Response:

Please refer to the response to ICLR IR1 1.1.

1.3 Similarly, how will FortisBC know the magnitude and distribution of seismic intensities? And when will FortisBC know this?

Response:

Please refer to the response to ICLR IR1 1.1.

1.4 What is the procedure and criteria for FortisBC to make a decision to turn off selected customers? On what data are the criteria based? How were they developed?

Response:

Currently, if FEI's system was damaged and as a result FEI was unable to provide service to a customer or a large number of customers, FEI would manually isolate the affected system and then turn off the affected customer(s) as per FEI's emergency response plan.

If the AMI Project is approved, FEI will finalize the details for incorporating AMI into the Corporate Emergency Program, including authority levels for decisions related to shutting off customers, during the Define phase. At that time, the appropriate training will also be provided to ensure employees at all levels are informed regarding the capabilities of the technology and how the technology can be applied during an emergency situation.

FEI uses the Incident Command System (ICS) for command and control of emergencies which is standardized, scalable and used by government and most other emergency agencies. Emergencies are managed at different levels, assessed for severity, and supporting functions are brought together based on the situation or need. FEI's approach to managing emergencies is consistent across the entire business. Training in the management of emergencies is provided on an as-needed or as requested basis and done in accordance with various standards and regulatory requirements.

Generally speaking, small emergencies, such as damaged gas services, are handled by frontline emergency personnel.

Larger emergencies, such as damage to critical gas mains, may be supported by an Area Command Centre or an Emergency Operations Centre activation, along with a field response by frontline emergency personnel. These responses are rehearsed, are coordinated and evolve with the support and engagement of FEI's Executive Leadership Team, with each level of the response understanding their roles and responsibilities.

FEI responds to gas-related emergencies across the province on a daily basis. Emergency response personnel receive annual training that is appropriate for their role. Additionally, FEI conducts in excess of 20 emergency exercises each year, most of which involve the participation of local emergency response agencies and other stakeholders. FEI is well connected with local, regional, provincial and Indigenous emergency management and response organizations.

All emergency response personnel have access to appropriate written instructions, plans and policies.

If the AMI Project is approved, the ability to remotely disconnect customers will be a new capability to FEI, the result of which will be increased public safety and an improvement in the customer experience. FEI will conduct internal workshops to discuss the use of remote disconnects during a variety of emergency scenarios. Earthquakes will be one of the emergency scenarios that will be considered and FEI's Emergency Response Plan and its System Preservation and Restoration (P&R) Plan will be updated appropriately.

1.5 Who will make the decision within FortisBC? What is their training and what instructions do they have?

Response:

Please refer to the response to ICLR IR1 1.4.

1.6 Since FortisBC has many thousands of customers, some part of the decision-making process might benefit from decision-support tools (e.g., databases, algorithms). What decision-support tools does FortisBC have for this purpose, how were they developed, by whom, and who will use them?

Response:

During an emergency, FEI is able to monitor its system in real-time, via numerous telemetry points that provide information on the system's pressure, flowrate and temperature. FEI builds and maintains hydraulic models of its systems and is able to manually run hydraulic modelling software to determine if portions of its system may be at risk under certain situations. FEI also utilizes this hydraulic modelling software to analyze the distribution of customer demand across its system. This demand footprint, when combined with FEI's telemetry real time data, can support decisions on how and when to shed load if faced with critical supply imbalances. In addition to this hydraulic modelling software, FEI also utilizes GIS software and other applications to develop predetermined shutdown plans and also create customized shutdown plans during actual emergency conditions. With these software tools, FEI is able to make dynamic decisions during emergencies and determine how best to maintain public safety and minimize customer outages if and when system isolations are required.

If FEI's AMI Project is approved, FEI will have access to a new technology platform that will allow the economic installation of additional distribution pressure, temperature, and flow sensors. These additional telemetry points will improve FEI's ability to monitor its system performance in near-real time. Also, FEI's ability to respond to emergencies will be further improved by AMI's ability to perform targeted remote disconnects based on circumstances and requirements. Should a customer's gas line break downstream of the proposed advanced meter, the meter will sense the high-flow condition and automatically close its internal valve. Further, if an advanced meter senses a rapid increase in the ambient temperature (such as due to structure fire), the meter will automatically close its internal valve. These actions will ensure only premises exhibiting signs of a damaged gas line or structure fire will have their gas service temporarily disconnected.

1.7 Does FortisBC have seismic-relevant data on its customer's buildings? That is, damage to a building is the prime factor in deciding to shut off gas to a building, so what data does FortisBC have for this purpose, and how does it enter into FortisBC's decision-making?

Response:

FEI does not have data relevant to the construction of customer buildings, specifically as it relates to the susceptibility to damage resulting from an earthquake.

1.8 Does FortisBC have a Standard Operating Procedure (SOP) for making and executing a decision to shut off service following a large earthquake?

Response:

FEI has developed pre-determined shutdown plans for a wide range of emergency events that include earthquakes; however, the degree to which these plans are implemented is situationally dependent. These pre-determined shutdown plans enable FEI, if required, to deploy field personnel and quickly respond to emergency situations on its system(s).

During the AMI planning phase, workshops will be held to determine how the AMI technology can be leveraged to enhance FEI's ability to respond to emergency events and emergency response plans will be updated accordingly.

1.9 Given the damage and disruption due to an earthquake, including likely loss of power and communications, how will FortisBC communicate with its SmartMeters? Has FortisBC assessed its ability to communicate with the proposed SmartMeters? If so, what is this reliability and how was it determined?

Response:

At this time, FEI has not conducted a detailed assessment of its ability to communicate with meters that will be installed as part of the AMI Project after an earthquake. Communications reliability will be highly dependent on the sites selected for Base Stations and the availability of backhaul bandwidth from cellular providers. As site selection has not been completed, an assessment is not possible at this time. However, since most meters in earthquake susceptible areas will have the ability to communicate with multiple Base Stations and the Base Stations themselves will have backup power supplies, FEI expects that if any communication disruptions result from an earthquake event, they would be minimal.

1.10 In areas where electric power fails, what will be the energy source to actuate valve closure?

Response:

As discussed in the Application and various IR responses,[1] the Sensus Sonix IQ meter to be installed during the proposed AMI Project is battery powered and is not connected to the electric power distribution grid. For this reason, meter functionality, including valve actuation, will not be affected by localized power outages.

1.11 Has FortisBC assessed the consequences of turning service off following a large earthquake? If so, what are those consequences?

Response:

FEI's focus following any emergency, including a large earthquake, is the safety of its customers, employees, and the public. In the event of a large earthquake, FEI's initial focus would be responding to emergency situations such as damaged infrastructure (including damaged service lines to premises), while maintaining gas service to other customers with gas lines that continue to operate safely.

Indiscriminately turning off gas service to customers following a large earthquake may result in a different emergency scenario: the unnecessary curtailment of gas supply to large numbers of customers whose service continues to operate safely. If gas service is unnecessarily turned off following a large earthquake, the piping, appliances, vents and chimneys would still need to be checked before the gas is turned back on by a qualified field technician. Consequently, if a large number of customers have their gas service turned off, and where their services were operating safely, these customers would unnecessarily be without gas for heat, hot water, cooking or other purposes for weeks or months. If this scenario occurred anytime during the winter months,

[1] Section 4.3.1 of the Application, Section 1.3.2 of the Util-Assist Report, the Executive Summary and Chapter 3 of the Exponent RF Technology Report, the responses to BCUC IR1 13.1, 26.1, 26.3, BCSEA IR1 33.1, CEC IR1 30.1, 32.2, and the data sheet included as Attachment 1 to CORE IR1.

subsequent cold weather conditions could severely impact the health and safety of FEI's customers.

1.12 Has FortisBC assessed the consequences of not turning service off following a large earthquake? If so, what are those consequences?

Response:

FEI has considered the consequences of not turning service off following a large earthquake and has determined the best option is to respond in a controlled manner based on the circumstances of the actual event.

FEI has developed shutoff plans and, if required in the circumstances, will implement these plans after an earthquake. In addition, on FEI's website[2] and during community events, public safety information is provided on how to prepare for an earthquake and what to do during and after an earthquake. FEI also provides information to the public on how to respond after encountering the smell of rotten eggs (which may be indicative of the presence of natural gas) or hearing the sound of escaping gas. FEI believes this balanced emergency planning and response approach best meets FEI's emergency response priority to ensure public safety. By assessing the situation immediately following a large earthquake, FEI will be able to, if required, quickly mobilize and shut off predetermined system valves to maintain public safety.

If, after a large earthquake, FEI unnecessarily turned off service to the more than 600,000 Lower Mainland customers, it would take months to relight all of these customers. If this occurred during winter months, the result could be significant health and safety impacts on customers and communities that did not otherwise have an actual gas emergency in their homes or facilities. Customers would be left without heat, hot water and cooking capacity and communities would find it challenging to support emergency response functions such as offering warm shelter and cooking facilities to community members in need. FEI's position on this matter is also supported by Technical Safety BC's Emergency Information Bulletin[3] which states "…depending on the time of year and type of event it may be advisable to leave heating appliances in operation to protect against freezing conditions".

Should the AMI Project be approved, FEI's ability to respond to emergencies following a large earthquake will be significantly improved by being able to perform targeted remote disconnects based on local circumstances and requirements. In addition, should a customer's gas line break downstream of the advanced meter, the meter will automatically sense a high-flow condition and close its internal shut-off valve. If an advanced meter senses a rapid increase in the ambient

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[2] https://www.fortisbc.com/safety-outages/preparing-for-emergencies/earthquakes
[3] https://www.technicalsafetybc.ca/alerts/information-bulletin-emergency-natural-disaster-protocol-electrical-and-gas-equipment-safety

temperature (such as due to a structure fire), the meter will also automatically close its internal valve. These actions will ensure that only premises exhibiting signs of a damaged gas line or structure fire will have gas service temporarily disconnected.

1.13 Has FortisBC assessed the error rate for turning service off following a large earthquake? (error rate is two-fold:
(a) services turned off where there was insufficient damage to justify shut off, and
(b) services not turned off where there was sufficient damage to justify shut off). If so, what are the results of that assessment, how was it determined and who made the assessment?

Response:

FEI has not assessed the error rate for turning services off following a large earthquake.

1.14 Has FortisBC assessed the seismic fragility of the SmartMeters it proposes to install? If so, what is that fragility and how was it determined and who made the assessment?

Response:

As explained in the response to ICLR IR1 2.6, Sensus has conducted extensive testing in accordance with industry standards to confirm the SonixIQ meters' ability to withstand mechanical vibrations and other environmental factors. FEI has not independently assessed the effects of seismic events on its proposed advanced meters.

1.15 Has FortisBC studied the use of seismic shut-off devices built into gas meters in Japan? If so, what lessons from Japan has FortisBC incorporated into its practice?

Response:

While FEI is anecdotally aware of the use of seismic shut-off devices built into gas meters in Japan, FEI has not studied this deployment in detail. Please also refer to the response to ICLR IR1 1.16 and 2.2.

1.16 Has FortisBC considered the inclusion of a seismic shut-off devices in its gas meters? If so, what was FortisBC's decision and how and on what basis was it made? If not, why not?

Response:

In Sections 3.4.2 and 4.3.2.4 of the Application, FEI describes how one of the drivers for the Project is to support safety and resiliency of the gas distribution system, including advancing emergency preparedness for natural disasters such as earthquakes.

With this in mind, and as discussed in the response to BCUC IR1 38.1, FEI did consider the implications of having automatic seismic shut-off valves[4] integrated into its advanced meters. However, for the reasons described below, FEI determined this option would impose an unacceptable risk to customer service reliability with no meaningful safety benefits. Most notable would be the potential for the indiscriminate and mass disconnection (due to the earthquake shaking) to large numbers of customers with gas services that continue to operate safely. Additionally, FEI confirms that residential meters which include an automatic seismic valve are not available in the North American market.

FEI's proposed AMI solution provides a more sophisticated and intelligent approach for responding to a major earthquake and the potential resulting damage to some customers' gas lines and equipment. Please also refer to Sections 4.3.2.4.1 and 4.3.2.4.5 of the Application, and the responses to BCUC IR1 2.1 and BCSEA IR1 18.1. FEI's solution would have additional benefits and would not have some of the major drawbacks inherent in the simplistic seismic-actuated shut-off valve approach.

Following are the major considerations that formed the basis for FEI's decision not to include seismic-actuated shut-off valves as part of the proposed AMI Project.

1. Mass outages from undesirable actuation: An earthquake event could result in minimal to no property damage, but still result in a widespread customer outages due to the actuation of many thousands of valves. For clarity, the valves may be activating in accordance with their specifications, but inappropriately and without any safety benefit in light of the actual circumstances. Depending on the severity and location of the earthquake, months-long outages to hundreds of thousands of customers could result from the indiscriminate and unnecessary actuation of the valves. This could result in significant negative impacts to customers and the public. FEI has quantified similar scale outages and provided order-

[4] In this instance, FEI uses the words "automatic seismic shut-off valves" and "seismic-actuated valves" to refer to a device at the customer premises that would have the means to sense seismic activity (above a certain threshold) and consequently shut off the flow of gas to that premise. These devices can also be referred to as seismic gas shut-off valves (SGSV) and earthquake actuated automatic gas shut-off valves (EGV). These devices have no external system to validate the actual occurrence of an earthquake.

of-magnitude estimates of this risk in Exhibit B-8-1-1, FEI's confidential response to CEC IR1 38.2 and BCUC IR1 16.2 filed in the TLSE Application; a copy of the latter response is attached as Attachment 1.16 to this response.

2. Potential for false actuations: Construction activity, large trucks, and other events causing localized vibration can cause the valves to actuate and interrupt the customer's gas supply. These events would generally be localized to a small area or a single premise, but depending on the frequency of occurrence, could impact FEI's operational resource requirements.

3. Technology is not available: To FEI's knowledge, no North American gas meter manufacturer offers seismic-actuated shutoff valve functionality built into their meters. Further, there is no Measurement Canada approved meter with an integrated seismic actuated valve that FEI can legally install to measure gas consumption for custody transfer purposes;

4. Automatic meter shut-off driven by unexpected gas flow is a more accurate approach: Configuring the advanced meters to automatically shut off based on high gas flow that is directly indicative of damage to downstream gas lines or appliances is a more accurate approach to ensuring customers with a safe operating gas service do not have service interrupted unnecessarily.

5. FEI would lose control of the gas system: In an emergency, FEI would rely on its ability to control which sections of the system get shut down and when. Seismic-actuated valves that automatically shut off gas when this is not needed would interfere with this control. In contrast, by using the functionality provided by the AMI project, FEI would have the ability to shut down sections of the system based on assessments made by qualified personnel of the actual circumstances unfolding at the time of the emergency.

6. Utility practice has not identified benefits: separately installed (i.e., external to the gas meter) seismic-actuated valves have been available within the North American market for several decades. FEI is not aware of any major gas utility in North America that is currently installing seismic-actuated valves on their system on a mass scale, presumably for the reasons discussed in this IR response.

7. Recommendations made in publicly available studies and regulatory decisions: FEI has reviewed publicly available studies and decisions commissioned by governments, regulators, and industry working groups and none have recommended system-wide installation of seismic-actuated valves.

8. Questionable risk reduction: there appears to be no agreement, even when not considering their downsides, that seismic-actuated valves provide any meaningful improvement in safety (especially in single family homes) or a reduction in fire ignitions. This is especially true when compared to other risk reduction measures such as excess flow valves, methane detectors, securing appliances, connecting appliances with flexible hoses, reducing the dependence on standing pilot lights, or a combination of all these measures.

FEI also commissioned an independent expert (D.G. Honegger Consulting) to provide an opinion on this subject. This included an examination of the technology as well as exploring the potential scale of the risk of a relatively small earthquake causing little to no damage, but resulting in significant and long-term outages to FEI customers. The report is included as Attachment 1.16b and supports FEI's view that seismic-actuated valves should not be included in the meters to be used on the proposed AMI Project.

In addition, Technical Safety BC (TSBC) administers the Safety Standards Acts throughout British Columbia and works closely with FEI to ensure safety standards are met. To date, TSBC has not required the installation of seismic valves. Furthermore, in 2019, TSBC issued an information bulletin[5] that provides gas appliance installation recommendations for premises that are within an active seismic zone. The bulletin does not provide recommendations for seismic valves and goes on to state "depending on the time of year and type of event it may be advisable to leave heating appliances in operation to protect against freezing conditions". This implies that the TSBC understands and has considered the significant implications of erroneously shutting off gas services to premises without evidence of damage and the importance of keeping gas flowing for the health and safety of people.

Finally, FEI notes that ICLR's information requests are preceded by a preamble that includes the following statement: "To reduce the risk of these sources of fire, Japan following the 1995 Kobe earthquake required every gas meter in the country to be replaced with a gas meter having an integrated seismic gas shutoff device (SGSD). FEI proposes an advanced meter replacement program that omits such a built-in SGSD. Including an SGSD adds little to the cost of the meter and the technology is proven and readily available." The preamble also includes a link to a paper from November 2020 (the Scawthorn Paper). In its cover letter enclosing its responses to ICLR's information requests, FEI addresses whether ICLR's preamble is appropriate and what if any effect it has from a process or evidentiary perspective. However, in order to be as responsive as possible, FEI adds the following.

FEI is open to considering new or further information that might contribute to improving safety and/or reliability. Correspondingly, it has reviewed ICLR's comments and the Scawthorn Paper. The Scawthorn Paper deals with broader issues related to earthquakes (and in particular potential fires that it suggests could be associated with them) and only to a very limited and scattered extent, with the issue of seismic actuated shut-off valves. Where it does deal with that issue, its comments are limited. The comments in the Scawthorn Paper are also supported by very little, if anything, by way of evidentiary reference. The Scawthorn Paper contains no discussion of specific shut-off devices and the risks they introduce to the reliability of the distribution system, and no discussion of whether residential meters incorporating SGCD are available in North America (which would be contrary to FEI's understanding, as noted above, that manufacturers for the North American market do not have gas meter products with this functionality). It contains no

[5] https://www.technicalsafetybc.ca/alerts/information-bulletin-emergency-natural-disaster-protocol-electrical-and-gas-equipment-safety

analysis of the costs to implement or operate and maintain such devices, if available. Notably, it also contains no discussion of the public health and safety risks that could result from an indiscriminate mass shutoff of gas service to hundreds of thousands of customers during cold winter conditions following an earthquake.

ICLR's preamble and the Scawthorn Paper both point to Japan, which has a system that to the best of FEI's knowledge is designed, constructed, operated, and regulated differently from FEI's system. No analysis has been provided to suggest that Japanese customers use natural gas in the same way as Canadian customers, that they interact with the system in the same way, or that the infrastructure, building codes and standards are the same or comparable in relevant respects.

FEI also notes that the Scawthorn Paper (on an early information page) refers to the fact that ICLR was established by insurers. To the best of FEI's knowledge, ICLR's board of directors is comprised mostly of insurance industry executives with a few academics. There is no industry representation on ICLR's board, and no representation from any other group outside of academia and the insurance industry.

1.17 Has FortisBC conferred with local fire departments, emergency managers, building departments or other agencies in including seismic shut-off devices in its gas meters? If so, what was the process and input FortisBC received? If not, why not?

Response:

FEI conducted a presentation related to the proposed AMI Project to the Fire Chiefs Association of BC (FCABC) to explain the benefits of the technology. Additional information has been provided to the FCABC and subsequent discussions have also taken place in which FEI received positive feedback related to the Project. The topic of seismic valves was not raised by any of the attendees at the meetings.

FEI also engaged with the City of Vancouver's (CoV) Lead Seismic Policy Planner to provide an overview of the AMI Project and discuss its safety benefits. The CoV representative acknowledged the safety benefits of FEI's proposed AMI technology, including the remote and automatic shut-off capabilities. The topic of seismic valves was also raised and the CoV representative expressed a preference toward the remote and automatic shut-off capabilities provided by the technology currently proposed by FEI.

Please also refer to the response ICLR IR1 1.16 related to the inclusion of automated seismic valves within the Project.

1.18 What is the vulnerability of FortisBC's operations center to a large earthquake? If its operations center is not functional following a large earthquake, what are FortisBC's contingency plans and capability, and how will a dysfunctional operations center affect FortisBC's ability to shut off service where needed?

Response:

The FEI Operations Centre building was designed as a "post-disaster" structure. Post-disaster buildings, such as FEI's Operations Centre, are designed with a higher seismic importance factor than a "normal" occupancy building. This means the Operations Centre has increased Lateral Force Resisting capacity than ordinary use buildings. It also means that for a given earthquake event that would affect this building, less structural and contents damage would result because the building is better able to withstand the effects of the earthquake-induced strong ground motion.

In the event that the primary FEI Operations Centre becomes unavailable, backup locations are also available and operational. These include redundant technology and systems to allow continued monitoring and control of the gas system, including the ability to shut off services where necessary. If the Operations Centre is unavailable or deemed unsafe to occupy, FEI's business continuity plans provide the necessary information to ensure a seamless transition from the primary to the secondary or tertiary locations as required.

FEI has well understood and rehearsed emergency response and business continuity plans that include regular activation and testing of the backup Operations Centres. These account for managing and mitigating the effects of any emergency or business interruption, not just those related to a seismic event.

1.19 If following a large earthquake FortisBC shuts off service to a large number of customers, what are FortisBC's plans for restoring service? How long would this take?

Response:

If FEI disconnects a large number of customers after a major earthquake, the amount of time to reconnect customers would be significant. FEI's first priority would be to ensure the natural gas system is safe. This would be achieved by shutting in the affected system (i.e., shutting in stations, closing pipeline/main valves, and closing the meter valves at a customer meter sets), conducting leak surveys, completing any required system repairs, and potentially purging sections of the system as required. After confirming the natural gas system is safe, FEI would commence customer appliance relights. Assuming a group of disconnected customers are in the same neighbourhood or community, FEI's field technicians would likely go door-to-door and purge the premises' service lines, inspect meter sets for proper operation, and then inspect the customer's gas houseline (at the meter set) and gas appliances. If after these steps are complete and the technician determines it is safe to turn the gas back on, the technician will then relight the customer's appliance(s). Depending on the number of disconnected customers, FEI may have to also utilize local licensed gas contractors and mutual aid agreements. FEI expects it would take weeks to months to relight a large number of customers after a large earthquake.

1.20 What is FortisBC's estimate of its liability for erroneously shutting off service where such service would not have been shut off by a reasonable decision-maker? Conversely, what is FortisBC's estimate of its liability for not shutting off service where such service would have been shut off by a reasonable decision-maker? How were these estimates arrived at, and by whom? What is FortisBC's resources to meet these liabilities?

Response:

Please refer to the response to RCIA IR1 44.1.

For the gas meter manufacturer of choice

2.1 Does Sensus have a gas meter with built-in accelerometer, earthquake detector and/or seismic shut-off capability? If so, how does it work, how has it been validated and where has it been installed? If not, has Sensus considered the inclusion of such devices in its gas meters?

<u>Response:</u>

The following response was provided by Sensus.

Sensus does not currently have a gas meter with these features. The SonixIQ meter does contain an internal shut-off valve that can be self-actuated, locally, or remotely operated by the Utility for any reason, including identification of a seismic event by an external data source. Sensus did evaluate including an accelerometer into the SonixIQ meter, however decided against it due to the potential for significant false positive notifications (e.g. heavy vehicle traffic, regular physical meter impact, construction, etc.).

2.2 Has Sensus studied the use of seismic shut-off devices built into gas meters in Japan? If so, what lessons from Japan has Sensus incorporated into its practice?

<u>Response:</u>

The following response was provided by Sensus.

Sensus hasn't studied this as meters used in Japan, along with physical meter locations, differ significantly from North American applications, rendering the study not applicable.

2.3 Does Sensus have a recommendation for its customers regarding seismic safety and/or meter operation vis-à-vis its products? If so, what is it?

<u>Response:</u>

The following response was provided by Sensus.

Sensus recommends that our customers work with local regulatory bodies to ensure compliance with local rules and regulations on this topic.

2.4 Does Sensus have any experience of its products being affected by earthquakes? If so, what was that experience?

Response:

The following response was provided by Sensus.

Sensus tests for and ensures compliance of all products against the required standards for vibration (including Seismic vibration per Telcordia GR63 Zone 4) and other environmental factors (temperature, pressure, salt, humidity, thermal shock, etc). Sensus does not have any data available about how its products perform during actual earthquakes.

2.5 For a building where Sensus gas meters are installed, if electric power service to that building fails, how does the meter operator communicate with the meter? If the meter operator wishes to remotely shut off gas service, how is that accomplished and what is the energy source to actuate valve closure?

Response:

FEI did not request a response from Sensus for this question. Please refer to the response to ICLR IR1 1.10.

2.6 What is the seismic fragility of Sensus's various gas meter products? How was that determined and who made those assessments?

Response:

The following response was provided by Sensus:

Sensus tests all natural gas meters against applicable standards, including ANSI B109, to ensure that our products meet the needs of the natural gas industry and our customers. Although B109 does not specify seismic fragility requirements, it does specify requirements for mechanical vibration and other environmental factors. Sensus SonixIQ meters have been certified to be in compliance with these requirements. Additionally, Sensus has tested the SonixIQ meter against Seismic Vibration per Telcordia GR63, Zone 4 severity.

Attachment 1.16

AMI provides FEI with a technology platform that will allow the economic installation of additional mid-point pressure and flow sensors, and tail-end pressure sensors. With this technology, FEI will be able to monitor, in near-real time, the performance of all stations throughout FEI's system. To support monitoring and forecasting the total system demand, AMI will provide FEI with the ability to monitor, in near real-time, all customer consumption. This means all meters[29], no matter the size, will be connected to the AMI network. As customer consumption information is collected throughout each hour, FEI will aggregate the total system demand and will be able to determine the granular demand in specific parts of the system. This near-real time aggregated total demand on the system of interest, and supply performance, will be used by FEI to determine which parts of FEI's system are vulnerable to a pressure collapse.

AMI will also provide the ability to remotely disconnect residential and small commercial customers, in order to decrease the possibility of a pressure collapse. Large commercial and industrial customer meters will not be equipped with remote shutoff valves, and so FEI will continue to rely on slower, manual processes to curtail these customers.

Regardless, FEI does not view temporarily shutting-off service to customers as a preferred option as it would still result in a customer outage and the need for a subsequent customer visit for appliance relighting. The preferred option is to utilize the TLSE Project storage to meet all customer demand during the no-flow event. By allowing FEI to strategically disconnect customers in a timely manner, AMI will decrease the possibility of a pressure collapse and allow for critical customers to remain connected. However, while AMI provides complementary functionality to TLSE, AMI alone will not stop a pressure collapse from occurring in all scenarios.

16.2 Please provide a detailed discussion of any other anticipated resiliency benefits from the implementation of AMI, including but not limited to how AMI could impact FEI's ability to:

- Ascertain the supply/demand on the system;
- Curtail customers/Implement a controlled shutdown; and
- FEI's process and timelines to resume service.

Response:

Please refer to the response to BCUC IR1 16.1 for details of how AMI supports ascertaining system supply/demand, accurately forecasting load for the duration of a gas supply emergency, and curtailing customer demand.

AMI is not a supply-side solution, so by definition would not add any supply or storage in the Lower Mainland region; hence, AMI would not contribute to meeting the MRPO. The only supply-side options that would provide FEI with the capability to withstand and recover from a no-flow

[29] Except for a small number of non-communicating meters as explained in the AMI CPCN Application.

event would be a combination of new storage and/or pipeline(s). As such, AMI is complementary to the TLSE Project, and is not a replacement or alternative for the Project.

Should all other gas transportation or storage options be exhausted and FEI is forced to disconnect customers, AMI would allow for a more timely resumption of service. The amount of time to reconnect customers in a large scale outage would vary and still be significant; however, AMI's capability of effectively tracking which customers were disconnected enhances the efficiency of the relight process.

AMI's ability to remotely disconnect customers to prevent a system pressure collapse would help minimize the number of customers that are disconnected from the system. As a result, FEI would have fewer customers to relight and would be able to complete the relight process more efficiently. Accordingly, the overall time to re-establish service to customers would decrease.

Once FEI secures a sufficient supply of gas, disconnected customers would be reconnected. This process would involve FEI calling the disconnected customers and arranging for a relight appointment. FEI is assessing the feasibility of using AMI to provide customers the additional option of a remote reconnect. If feasible, the remote reconnect option could involve asking customers pre-screening questions (over the phone) to confirm they are capable of safely relighting their appliance(s). If the customer wants to relight their appliance(s) and demonstrates the necessary knowledge, FEI would send a command, via the AMI network, for the meter to perform a remote dial test to confirm the integrity of the customer's house piping and appliance(s). If the meter passes its remote dial test, the customer would be informed that the appliances would be ready to be relit.

Manually relighting all Lower Mainland customers would take months to complete, even with all available FEI and provincial resources, local gas contractors, and mutual aid agreements. However, if FEI can use AMI to remotely disconnect customers and prevent a pressure collapse, this would result in fewer customers requiring a relight and save potential days to weeks required to repressurize a collapsed system. If a pressure collapse is averted but a large number of customers were disconnected, it could still take months to relight all these disconnected customers. If the remote reconnect option is available, FEI would have greater flexibility to relight customers. This greater flexibility should decrease the overall amount of time to relight customers disconnected from FEI's system, however FEI is unable to quantify this reduction in advance. The total time should decrease by approximately the same percentage of customers who successfully relight their appliances via the remote reconnect option.

On pages 85-86 of the Updated Public Application, FEI explains the T-South Expansion alternative. FEI states: "The expansion provides very little new resiliency from FEI's perspective, since it does not reduce the current single point of failure risk and adds no pipeline diversity."

OPINION ON POTENTIAL RISK REDUCTION PROVIDED BY EARTHQUAKE ACTUATED AUTOMATIC GAS SHUTOFF VALVES

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About the Author

Douglas Honegger has nearly 40 years of experience in a broad range of consulting activities related to understanding the response of structures, structural components and equipment to extreme loading resulting from earthquake hazards, blast, and impact. Since 1995, Doug has operated a sole proprietor engineering consulting business as D.G. Honegger Consulting. Doug has been working on seismic issues in British Columbia since 1993.

Doug is a recognized expert in the evaluation of the impacts of large permanent ground deformation on buried pipelines and conduits and continues to advance the state of practice through active laboratory and field research activities. This experience began with work on the 1984 ASCE Guidelines for the Seismic Design of Oil and Gas Pipeline Systems. He led the effort to revise the pipeline-related portion of the 1984 guidelines for the Pipeline Research Council International (PRCI), 2004 and again in 2017. He led another PRCI effort to develop guidelines for pipelines subject to landslides, and subsidence hazards in 2009. In 2019, he completed a seismic guideline for Canadian energy pipelines for the Canadian Energy Pipeline Association. He has been a co-instructor of a continuing education course on the seismic design of buried pipelines. He is currently a guest lecturer for an introductory pipeline engineering course at the University of British Columbia, Canada.

Doug was the principal investigator for the American Lifelines Alliance (ALA), a FEMA project focused on promulgating national guidelines and standards to improve utility and transportation system performance when subjected to natural and man-made hazards (www.americanlifelinesalliance.com). During course of the ALA project (1998 through 2009), ALA projects addressed topics related to improved algorithms for estimating seismic damage to water pipelines, recommended practice for assessing vulnerability and design of buried pipelines, revised seismic design requirements for aboveground steel storage tanks, and guidelines for determining the appropriate scope of work to support risk management decisions for water, natural gas, and oil pipeline systems. Several of the ALA guideline documents are still relied upon to establish performance goals and design criteria. Since 2009, Doug has privately kept the ALA website open for use by the lifeline engineering community.

Doug has studied the causes of post-earthquake fire ignitions since the late 1980s with a study of the distribution of fire-ignition sources and gas appliance damage in the 1987 Whittier earthquake. He has had his own consulting practice, D.G. Honegger Consulting, since 1995. Prior to that, he investigated post-earthquake fire ignitions and gas pipeline damage in the 1989 Loma Prieta and 1994 Northridge earthquake. In 1992, he arranged for the secretariat for the standard related to earthquake actuated automatic gas shutoff valves, to be transferred from the American Society of Mechanical Engineers to the American Society of Civil Engineers (ASCE) and became the first chairman of that committee. Much of the valve actuation modification in the first publication of ASCE 25- *Earthquake Actuated Automatic Gas Shutoff Devices,* was based upon Doug's research related to the 1994 Northridge earthquake. He remained the chair of the ASCE 25 committee until 2005 and participated in the revision cycle for ASCE 25-16.

Doug was the lead consultant to ASCE on the ASCE 25 project to provide a 2002 report to the California Seismic Safety Commission (CSSC) on improving natural gas safety in earthquakes. Based upon his experience with the ASCE 25 and CSSC work he was selected by the Applied Technology Council to be their technical consultant for preparing a report on recommended requirements for automatic gas shutoff valves in Italy.

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ACRONYMS

AMI:	Automatic Meter Infrastructure
ASCE:	American Society of Civil Engineers
CSSC:	California Seismic Safety Commission
EGV:	Earthquake-Actuated Automatic Gas Shutoff Valve
FEI:	FortisBC Energy Inc.
FEMA:	Federal Emergency Management Agency

EXECUTIVE SUMMARY

FortisBC Energy Inc. (FEI) is in the planning stages of an Advanced Meter Infrastructure (AMI) project in its service area in British Columbia that would involve, among other things, installation of advanced, "smart meters" to record gas consumption and communicate meter data to FEI remotely. Additionally, the type of AMI gas meter that FEI is considering will allow remote interruption and restoration of gas service and the capability to shut off gas service if a high flow condition, indicative of a gas line break, is detected.

There have been suggestions that FEI also incorporate a capability to automatically shut off gas service based upon earthquake ground motions above a certain threshold. To the author's knowledge, there are no smart meters with this capability in the North American market and no gas utility in North America installs earthquake actuated automatic gas shutoff valves (EGVs) on their system. EGVs are available as stand-alone devices that operate separately from a smart meter. Installation of this class of EGVs is restricted to the customer's piping that ends at the gas meter. This report presents information on what the benefits and drawbacks might be if an EGV capability could be implemented as part of the AMI project.

In the author's opinion, if there was an opportunity to add an EGV capability to the AMI project, the benefit would be minimal in terms of reduced safety risks and reduced post-earthquake fire ignitions for the following reasons:

1. Natural gas has historically been a contributing factor in 15% to 50% of post-earthquake fires. This percentage is likely lower today because of the elimination of live pilot lights, requirements to anchor gas appliances and use of flexible hose connectors.

2. Improvements in gas appliance operation and installation practices have likely reduced the potential for gas as a source of post-earthquake fire ignitions relative to ignitions related to electricity. Therefore, potential improvements in life-safety from installing EGVs is considered marginal.

3. An EGV does not prevent a gas flame from igniting a fire when the ignition occurs during or several minutes after earthquake ground shaking as pressurized gas remains in the house lines.

In addition to having minimal benefit in terms of improved safety and reduced fire ignitions, universal installation of EGVs on all gas services could have serious detrimental impacts. Because it is not possible to define EGV actuation levels based upon the likelihood of damage to structures and components of customers gas systems, EGV actuation levels must be biased to the low side. For the case of universal EGV installation, this creates the potential for unnecessarily shutting off service to more than 100,000 customers for up to several months, leading to a need for many to seek temporary shelter and causing substantial business interruption losses.

1 BACKGROUND

FortisBC Energy Inc. (FEI) is in the planning stages of an Advanced Meter Infrastructure (AMI) project in its service area in British Columbia that would involve, among other things, installation of advanced, "smart meters" at the premises of FEI's customers to record gas consumption and communicate meter data to FEI remotely using radio frequency technology. The AMI gas meters that FEI is contemplating for installation as part of this project are planned to include two safety measures that would mitigate against the risk of harm from seismic activity and the adverse contribution of gas services in the event of rapidly spreading post-earthquake fires:

1. High flow shut off. If the AMI gas meter detects gas flow above a set threshold through the meter, it will shut off gas flow to the customer; and
2. Remote connect/disconnect functionality that would allow FEI to disconnect/reconnect individual meters or groups of meters.

Conditions that constitute excess flow will vary depending upon the total amount of gas consumed by gas appliances. The flow rate at which excess flow shut off would be initiated needs to be greater than the flow that would occur if all gas appliances were functioning at their maximum capacity. Such a high flow rate would occur if a gas appliance hose connection were to fail or if an interior house line were to rupture. However, small gas leaks would likely not lead to shut off of gas service by an excess flow valve at the gas meter. Detecting a small leak could possibly be accomplished by developing software to evaluate output from a smart meters and identify anomalous gas usage.

The ability to remotely shut off gas supply at the gas meter allows FEI to rapidly respond to customers reporting a possible gas leak and to isolate gas service to multiple customers in a specific area if conditions warrant such action. Two hypothetical conditions that might warrant shutting off gas to customers in a specified area are provided below:

- Gas service is cut off to customers in a several block area that is in the path of a rapidly spreading fire to prevent gas lines in the buildings from becoming a source of additional fuel.
- Gas service is cut off to customers in an area of severe building damage to allow rescue operations to occur without the risk of fire or explosion from damaged gas appliances or piping.

There have been suggestions in public forums (e.g., McGillivray, 2021) that FEI also incorporate an automatic gas shut-off capability that would be triggered by earthquake ground shaking above a certain threshold. To the author's knowledge, there are no smart meters with this capability in the North American market. Adding such a capability to the AMI project would require a separate research and development project to perfect the technology and subsequent partnering with a utility meter manufacturer for product development and certification. However, EGVs are available as in-line devices that gas customers can install on the customers piping downstream of the FEI meter.

D.G. Honegger Consulting was engaged by Farris LLP to provide an opinion on the added risk mitigation that might be provided if earthquake-actuated automatic gas shut-off capability existed. The opinions expressed in this report are based upon extensive experience of the author in investigating the role of natural gas in post-earthquake fire, leading efforts to update standards for earthquake-actuated automatic gas shut-off valves (EGVs), leading the effort to develop recommendations for improving natural gas safety in earthquakes, and decades of experience in assessing the response of energy pipelines and industrial equipment to earthquake loading.

To the author's knowledge, no gas utility companies in North America install EGVs on their pipelines and equipment. EGV installation is limited to the gas customer's piping which is downstream of the utility meter.

Ideally, an EGV would shut off the source of gas when earthquake motions are severe enough to potentially damage structures, gas piping, gas appliances, vents, and flues. The pilot light would be extinguished after the gas remaining in the houseline dissipates, eliminating the possibility of the pilot light igniting flammable or spilled materials.

Unfortunately, the level of ground shaking associated with such damage cannot presently be estimated accurately because of the large variations in building construction. The inability to reliably predict damage means that current standards for seismically actuated devices are intentionally biased toward actuation at lower levels of ground motion.

Questions regarding the risk reduction associated with requiring gas customers to install EGVs go back several decades. The first performance standard for EGVs was American Gas Association (AGA) standard Z21.70 *Earthquake Actuated Automatic Gas Shut-off Systems*, which was approved in 1981. The single large fire in the Marina District of San Francisco following the 1989 Loma Prieta earthquake reinvigorated interest in mandating installation of EGVs. However, detailed examination of the specific role of natural gas services in post-earthquake risk did not occur until after the 1994 Northridge earthquake.

Following the Northridge earthquake, the Federal Emergency Management Agency (FEMA) funded several research projects that examined the performance of buildings and lifeline systems (electric power, water, natural gas, waste-water, transportation, and communication systems). One of these projects was awarded to investigate the relationship between the severity of earthquake ground shaking and fire ignitions and perform testing to characterize the dynamic response of EGVs on the market at that time (Honegger, 1995). While becoming rather dated at this point, the research performed following the 1994 Northridge earthquake remains the best source of data for examining the means to improve safety related to post-earthquake performance of natural gas services for housing stocks common to North America.

In the years following the Northridge earthquake, the California Seismic Safety Commission (CSSC) began to be pressured, largely from EGV manufacturers, to recommend a state-wide mandate for the installation of EGVs on gas customer services and prevent installation of an excess flow valves on the main customer pipeline as earthquake safety measure. There was no performance track record on the past performance of EGVs on the market at the time since no system was in place to keep track of particular models installed, how they were installed, or track information on actuation rates, both from earthquake shaking and other vibrations.

In 2001, Southern California Gas Company and Pacific Gas and Electric Company provided funds to support a task committee of the American Society of Civil Engineers (ASCE) ASCE 25 standard committee. The purpose of the ASCE 25 task committee was to provide information on potential benefits and drawbacks of a wide range of measures to limit post-earthquake fire ignitions related to natural gas. The 26-member task committee was chaired by a member of the CSSC and included representation from gas utilities, EGV manufacturers, the State of California office of emergency service, municipal fire departments and building and safety personnel, realtors, and academia. The ASCE 25 task committee issued a report to the CSSC in 2002 that was published as CSSC report SSC-02-03 in response to an initiative in the California Earthquake Loss Reduction Program related to "Educate local governments and the public on the application of gas safety devices such as automatic shut-off valves."

In terms of life safety, the CSSC report concludes that the safety risk to individuals in single family homes from earthquake-triggered fires is low because experience in past earthquakes indicates low building height combined with doors and windows provide occupants several direct evacuation paths. Thus, the impact of earthquake-triggered fires is largely financial. Potential financial impacts of post-earthquake fire damage on individual homeowners are mitigated to some extent by the homeowner's home insurance, which covers fire loss even if caused by an earthquake.

The life-safety risk for occupants of multi-unit residential buildings can be much more serious if the building suffers significant earthquake damage that can block corridors and stairwells or otherwise trap occupants.

The CSSC report did not recommend requiring EGV installation and noted that there are a range of actions that can be taken to improve natural gas safety in earthquakes, each with advantages and disadvantages, that are best selected on a case-by-case basis by individuals and communities. In 2005, the California Department of Housing and Community Development's Division of Codes and Standards issued Information Bulletin 2005-02 (SHL) that stated there was insufficient evidence to support a statewide requirement for the installation of seismic gas shut-off devices and/or excess flow valves. Instead, it was left to local governments (Attachment 1).

There are a limited number of cities that have implemented mandates for customers to install EGVs on their gas line (e.g., Los Angeles, Santa Monica, West Hollywood could be identified from EGV manufacturers web sites). Several other cities in California have passed regulations to require either an earthquake actuated or excess flow valve, essentially treating either device as equally effective in reducing the potential for natural gas to contribute to fire damage.

It is the author's experience that mandated installation of EGVs is based upon a misunderstanding of the role of natural gas appliances and house lines in post-earthquake fire damage. Natural gas is a fuel and will not ignite unless the concentration of gas is within a narrow range and there is an ignition source.

This report presents the following information:

1. A brief description of the seismic hazard in the Lower Mainland.
2. An overview of past experience with post-earthquake fire ignitions for North American earthquakes and the role of natural gas as a fuel for such ignitions.
3. A summary of past residential gas service damage in past earthquakes.
4. Performance requirements specified in the U.S. standard for EGVs that are marketed for installation on gas customer piping downstream of the utility meter and potential consequences of universal EGV installation for a hypothetical earthquake scenario.
5. Alternatives means to improve natural gas safety in earthquakes without EGVs.
6. Concluding remarks advising against widespread installation of EGVs given other safety features of the FEI AMI project.

2 EARTHQUAKE HAZARD IN THE LOWER MAINLAND

Earthquake activity in southwest British Columbia is driven by the subduction of the Juan de Fuca Plate beneath the North American Plate as illustrated in Figure 1. This subduction can produce three different types of earthquakes. The most highly publicized type of earthquake is caused when driving force at the interface between the Juan de Fuca Plate and the North American Plate exceeds the frictional restraint. This can result in a very large "mega thrust" earthquake with a moment magnitude (M_w) greater than M_w 8.0. The source of this earthquake is far offshore and is likely to impact Vancouver Island most-seriously. There are two other types of earthquakes that can produce greater damage in the Lower Mainland. The bending of the Juan de Fuca plate can result in "in-slab" earthquakes at great depth within the Juan de Fuca Plate. The 6th generation seismic hazard model for southwest British Columbia considers three separate zones for these earthquakes based upon the depth of the Juan de Fuca Plate as shown in Figure 2. This type of earthquake is typically the dominant earthquake hazard for the Lower Mainland. The 2001 Nisqually earthquake in Washington state is an example of this type of earthquake. Earthquakes can also occur as a result of strain in the North American Plate. These "crustal" earthquakes have the greatest potential for damage as they are closer to the surface. The 1946 M7.3 earthquake that occurred in central Vancouver Island, the largest earthquake to occur in southwestern British Columbia, was a North American Plate earthquake.

In summary, there is a potential for earthquakes sufficient to cause significant damage with locations beneath Vancouver Island and all of the developed region of the Lower Mainland.

3 SUMMARY OF MODERN POST-EARTHQUAKE FIRE IGNITION STATISTICS

Most of the post-earthquake fire research conducted to date has been related primarily to identifying potential areas at risk for conflagration and estimating the risk for potential fire losses (Scawthorn, 1985, 1986, 1987). This area of research has focused on developing empirical relationships between total number of earthquake-related fires normalized to a building parameter (normally square footage) and a measure of ground shaking, typically peak ground acceleration. From the standpoint of investigating the response of firefighting resources, the nature of the ignition is not necessarily of primary importance for such studies. The results of such conflagration studies are generally directed at two audiences:

1. Insurance companies that are concerned about fire losses resulting from a conflagration that could burn 10s to 100s of city blocks. Fire losses are covered as part of a standard fire insurance policy and a large conflagration could severely damage the financial stability of the insurance market.

2. Municipal and regional government agencies that are interested in identifying potential weaknesses in the fire response infrastructure such as water supply, available engine companies, and means of improved communication and coordination to reduce the potential for large areas of fire damage. Widespread fire damage can put a strain on emergency services (shelter, food, medical care) and lead to extended business interruption which reduces overall economic activity, including tax revenue.

Typically, the role of natural gas in fire ignitions is not considered in studies of the potential consequences of post-earthquake fire ignitions as the sources of ignition is not important. The focus is on the spread of numerous, isolated fires, regardless of ignition source. Questions regarding the efficacy of widespread EGV installation in reducing post-earthquake fire risks require that the role of natural gas usage as a source of fire ignition be examined in detail. One of the biggest challenges in this regard is that there has not been a large earthquake within an urban environment representative of the building practices in the United States or Canada that has generated any significant number of fire ignitions since the 1994 Northridge earthquake. The reason for this is unclear but two factors may play a role. One is the increased practice, or requirements, that gas appliances need to be restrained to withstand earthquake ground shaking. The other is the gradual elimination of the opportunity for a gas flame to be a source of ignition as gas appliances with a continuous pilot light are replaced with appliances that do not require a live pilot light. As old gas appliances wear out and are replaced, the risk of an ignition from natural gas appliances becomes more remote. The role of natural gas in post-earthquake fires will become mostly limited to flammable material coming into contact with a gas flame as a result of earthquake ground shaking. The installation of EGVs would not significantly reduce this ignition potential because of the residual pressure in the house lines. Another potential future role of natural gas in post-earthquake fires would be as an additional fuel for an ignition from another source, often electrical in nature.

Determining the source and the primary fuel for a post-earthquake fire ignition typically requires a review by the fire department. Information from three California earthquakes where this type of fire investigation was carried out include the 1987 Whittier Narrows, 1989 Loma Prieta, and 1994 Northridge earthquakes. A summary of the post-earthquake fire statistics for these three earthquakes is presented below. Damage from post-earthquake fires has been limited in all North American earthquakes since 1994. Scawthorn (2011) notes that only one earthquake related fire occurred in each of the 2000 M5.2 Napa, 2001 M6.8 Nisqually, and 2002 aftershock of the M7.8 Denali, Alaska earthquake, and the 2003 M6.5 San Simeon earthquakes.

The most recent large earthquake in California was the 2019 Ridgecrest M6.4 and M7.1 earthquake sequence. Based upon statements attributed to the Kern County Fire Department, they responded to one structure fire following the M6.4 earthquake on July 3rd and two fires the evening of the July 4th M7.1 earthquake (ABC7, 2019, VC Star, 2019). The statements did not indicate the underlying cause of the fires.

3.1 1987 Whittier Narrows Earthquake

The Whittier Narrows earthquake occurred on the morning of October 1, 1987, with a magnitude of 5.9, followed by an aftershock of 5.3 on October 4. Southern California Gas Company operates the natural gas distribution system in the region. Investigations following the Whittier Narrows earthquake provide some unique information on the effects of a moderate earthquake in an urban area.

The area affected by the Whittier Narrows earthquake is under the jurisdiction of the Los Angeles Fire Department. The day of the earthquake, the Los Angeles Fire Department responded to 1,185 incidents, compared to a daily average of 750 responses. However, 475 of these were reported between 7:42 AM and 11:00 AM on the morning of the earthquake. Of the 1,185 incidents, 155 involved fire and 61 were in response to a structural fire. Six fire ignitions were attributed to the earthquake on October 1, 1987—three involving natural gas and three involving ignitions by electric equipment.

This experience seems to support a conclusion that post-earthquake fire ignitions may be small relative to the typical the number of fire incidents that need to be responded to. If conditions are suitable for a fire to grow to a conflagration, the primary impact of the earthquake is to impair normal fire-fighting resources. Fortunately, the damage to the infrastructure necessary to respond to fire incidents was not impacted by the small magnitude of the Whittier earthquake event.

3.2 1989 Loma Prieta Earthquake

The M7.2 Loma Prieta earthquake occurred on October 17, 1989 at 5:04 PM, approximately 97 kilometers south of San Francisco. The earthquake severely damaged approximately 900 homes near the epicenter and in the San Francisco Bay area. The damage in the Bay area resulted from amplification of the ground motions at the surface by soft soils and liquefaction of soils associated with land reclamation projects, some dating back to the 1800s. Similar soft soil amplification is likely to occur in parts of Fraser River valley.

Although the earthquake caused fire ignitions near the earthquake source, San Francisco suffered the greatest number of post-earthquake fire ignitions. A summary of the fire statistics for the Loma Prieta earthquake is shown in Table 1.

The cause for the fire ignitions in San Francisco (as identified in the fire incident reports) is shown in Table 2. Assuming equal likelihood for gas or electricity as a cause for “stove” and “unknown,” natural gas could have been a factor in 34% of the fire ignitions, while electricity could have been a factor in 56%.

3.3 1994 Northridge Earthquake

Occurring on January 17, 1994, at 4:31 AM, the Northridge, California, earthquake had a moment magnitude of 6.7. The epicenter was located in the city of Reseda, near the center of the San Fernando Valley. The earthquake resulted in the total loss of electric power to the City of Los Angeles and adjacent areas.

Table 3 summarizes the distribution of earthquake-related fire ignitions and the response by various fire departments within the first 24 hours following the earthquake. The number and distribution of fire ignitions differ slightly among investigators, but the combined total of 110 earthquake-related fire ignitions is representative of the range of 85 to 120 reported by other investigators.

The City of Los Angeles, which includes the San Fernando Valley, sustained 77 of the 110 earthquake-related fire ignitions on the day of the earthquake. Fifty-five of these occurred in residential structures: 35 in one- or two-family residences and 20 in multi-family residences. A total of eight fire ignitions occurred in schools, offices, or commercial properties. Preliminary statistics on fire ignition response by the Los Angeles Fire Department indicate that 13 fire ignitions had a natural gas appliance as the source of heat ignition. The Los Angeles Fire Department conducted a separate investigation within a few months following the Northridge earthquake, and identified 38 incidents where natural gas may have contributed to the fire ignition. Of these, 27 were in single- or multi-family residences and 22 involved gas appliances with water heater damage, accounting for 16 fire ignitions.

3.4 Other Earthquake Fire Ignition Experience

Similar statistics on the distribution between total post-earthquake fire ignitions and post-earthquake fire ignitions where natural gas may have played a role are provided in Table 4 for U.S. earthquakes dating back to 1964.

The variability in data reported for the same earthquakes in Table 4 arises from differences in reported measures of magnitude, the fact that reported incidents may actually involve multiple structures, and the difficulty in segregating earthquake related fires from the total. The data in Table 4 indicate that gas plays a role in 15% to 50% of all earthquake related fires. A consideration that has not been captured in data collected to date is the likelihood of initial ignition of another fuel (e.g., fabric, paper, cooking oils) prior to natural gas becoming a dominant feature in the forensic investigation of a fire. Without an ignition source, natural gas is not a significant factor in post-earthquake fire ignitions.

As noted previously, the role of natural gas in earthquake-related fires is likely much lower today than it would have been several decades ago since the need for a pilot light has been eliminated from almost all new residential gas appliances. Furthermore, seismic restraint of gas water heaters is required in British Columbia. These two factors will further diminish the number of post-earthquake fires related to natural gas in the future.

Some caution is necessary when extrapolating ignition information from past earthquakes. Nearly every major earthquake in California has demonstrated some seismologic characteristic that was previously unknown or considered insignificant. Similarly, future earthquakes may produce quantities and types of infrastructure damage not previously observed. There is inherently a large amount of variability in the earthquake ignition statistics that is driven by differences in ground motion severity, building density, building construction materials, the relative dependence upon electricity and natural gas for heating and cooking, and weather conditions.

This large uncertainty is reflected in the limited number of fire ignitions in the 2010-2011 Christchurch, New Zealand earthquake sequence compared to what would be considered typical values based upon existing models. The need to reexamine earthquake ignition models was highlighted in a reconnaissance report for the 2010-2011 Christchurch, New Zealand earthquake (TCLEE, 2012). Table 5 from the TCLEE report lists fires for the 16 days following the September 4th, 2010 M7.1 main shock that were determined to be earthquake related by the New Zealand Fire Service. Of the five fires attributed to the earthquake on September 4th and 5th, two were related to chimney damage and the remaining three were caused by a fallen heater (presumably electric), electrical component failure, and a heat source close to combustible material. The low number of ignitions is particularly interesting considering the earthquake occurred near the end of the lunch hour where restaurants would have been actively preparing food and the presence of open cooking flames would seem fairly high in the central business district which suffered major structural damage. Indeed, over 20 fires over the same reporting period as Table 5 were characterized as related to cooking but not caused by the earthquake.

4 PAST EARTHQUAKE PERFORMANCE OF GAS APPLIANCES

The most significant contributor to natural gas becoming a fuel for post-earthquake fires is damage to unrestrained or poorly restrained gas appliances, particularly gas-fired tank water heaters. Some information on the earthquake damage to natural gas appliances is available for the 1987 Whittier Narrows, 1989 Loma Prieta, and 1994 Northridge earthquakes.

Service restorations following the Whittier Narrows earthquake was largely done by Southern California Gas Company (SoCalGas) personnel without assistance from outside gas utility personnel. Table 6 provides a summary of the types of damage to gas appliances and services based upon records for 1,920 repairs performed by SoCalGas personnel. The most common types of repair were to an appliance connector (39%), supposedly related to shifting of unrestrained gas-fired equipment. Damage to water heater connections accounted for nearly half of all gas appliance connection damage. Other significant sources of damage included house lines (26%) and the meter set assemblies (20%).

McDonough (1997) provides a qualitative measure of the types of damage observed by Mountain Fuel Supply Company personnel sent to assist Pacific Gas and Electric in restoring gas service following the 1989 Loma Prieta earthquake. Personnel from Mountain Fuel Supply Company worked for 16 days restoring service in three cities within approximately 20 km to 45 km of the earthquake epicenter: Los Gatos, Cupertino, and Mountain View. Following their return from restoring earthquake service, personnel were asked to complete a questionnaire regarding their observations based upon their best recollections. From these questionnaires, McDonough (1997) presents the trends with respect to types of damage in Table 7. This information is clearly not scientific, being based upon recollections of personnel over a period of more than 2 weeks and without prior knowledge that they would be asked to complete a questionnaire. What is obvious is the prevalence of damage to water heaters and vent piping. Based upon responses to the questionnaire, water heater damage was present in roughly 40% of the homes and damage to vent piping was present in roughly 60% of homes. Damage to interior piping and meter sets was much less frequent with percentages ranging from 4% to 9%.

A unique aspect of the Northridge earthquake was the response of FEMA. FEMA established a rapid reimbursement mechanism for homeowners to submit claims for damage to gas appliances. More than 400,000 claims were made for water heater damage and more than 700,000 claims were made for all gas appliance damage (e.g., water heaters, stoves, furnaces, ranges, and dryers). Claims ranged from repairs of minor damage to replacement with no information available on the type of damage. Multiple claims could have been submitted by a single property owner for damage to multiple appliances. Honegger (1995) had access to data from approximately 75% of the FEMA claims. A comparison of the levels of ground shaking in the Northridge earthquake and the distribution of claims for only water heater damage and claims for all gas appliances revealed similar trends in the concentration of claims with ground motion severity.

The occurrence of 54 post-earthquake fires related to natural gas is surprisingly low given the hundreds of thousands of claims for damage to gas appliances following the Northridge earthquake. One likely reason for this is the fact that numerous conditions are necessary for gas ignition (see, for example, Williamson and Groner, 2000).

The ignition of leaking gas requires an ignitable mixture of gas and oxygen between the approximate range of lower (5%) and upper (15%) explosive limits and an ignition source. This can occur in the presence of a pilot light (which, as noted previously, is becoming rare) or when an electric spark occurs when a piece of electrical equipment is turned on. For natural gas that is lighter than air and tends to disperse, the rate of gas leakage capable of igniting is related to the air exchange rate in the area of the leak. The likelihood of ignition is higher in conditions where poor air mixing allows formation of pockets of higher concentrations of gas.

Based on a review of the causes of fire ignitions in recent earthquakes, the following points summarize fire ignition scenarios involving gas or electric service. These scenarios incorporate the necessary presence of a fuel source and an ignition source.

- An electric-powered device is displaced or damaged and comes into contact with a quantity of fuel. Even if electrical service is lost nearly immediately, when electric power is restored, the device causes the flammable fuel to ignite. An example would be a high-intensity light falling onto a polyurethane mattress.
- A gas appliance (e.g., hot water heater) is overturned or shifts, rupturing the gas line to the appliance or the gas connector, and the released gas is ignited by a flame or spark.
- Building earthquake damage is sufficient to damage gas piping within the walls of the building and the released gas ignites due to an open flame or an electric spark.
- Containers holding flammable liquids (e.g., gasoline, charcoal lighter fluid) are thrown to the floor by the earthquake, and an open gas flame or an electric spark ignites the vapors from the spilled liquid.
- Cooking oils and other kitchen fuels are spilled during the earthquake and are ignited by electrical or gas-based cooking equipment.
- An open flame from a pilot light, candle, or cooking flame contacts a quantity of fuel such as spilled cooking oil, flammable vapors, or building debris.
- Arcing from crossed wires or transformer damage ignites brush near a structure.

In the absence of a gas appliance with a pilot light, the primary source of post-earthquake fire ignition will be electrical sparks or electrical appliances that can become a source of heat sufficient to ignite nearby material. Fire ignitions caused by operation of gas appliances can occur during shaking where combustible material is displaced close to the gas flame. This type of ignition would not be prevented by an EGV since the appliance would continue to function because of the quantity of pressurized gas remaining in the house lines. An operating gas appliance can cause an ignition after the earthquake shaking ceases if the earthquake leads to spills of highly volatile combustible fuels (e.g., gasoline, kerosene, charcoal lighter fluid) in the vicinity of an operating gas appliance. The ability of an EGV to reduce the potential for this type of ignition requires that the time between a spill and ignition be greater than the time for the gas appliance to consume the gas that would remain in the house line after gas is shut off by the EGV. Of course, this type of ignition can be easily prevented by not storing such materials near gas appliances.

5 EARTHQUAKE SHUTOFF VALVE ACTUATION LEVELS

Implementation of wide-spread installation of EGVs requires consideration of what an appropriate activation level is. The most practical approach is to adopt an existing EGV standard that has explicitly defined actuation levels and qualification requirements. Activation and non-activation requirements for residential EGVs in the United States is defined in ASCE standard 25-16, *Earthquake Actuated Automatic Gas Shutoff Devices* (ASCE, 2016) The ASCE 25 standard committee was established in 1991. Prior to 1991, EGVs complied to American Gas Association standard Z21.70, *Earthquake Actuated Automatic Gas Shutoff Systems*.

5.1 Background on ASCE 25 Development

Substantial work on ASCE 25 did not occur until the occurrence of the 1994 Northridge earthquake and the extraordinary amount of damage data collected afterward. The committee obtained funding to study relationships between variations in ground motions and post-earthquake fire locations and perform testing to investigate the actuation characteristics of EGVs on the market at that time. The approach used to investigate the Northridge data and subsequent findings are detailed in Honegger (1995, 1997) and summarized herein.

Data available from the Northridge earthquake included mapped locations of all earthquake-related fires and locations of strong ground motion recordings. The governing location for onset of actuation was conservatively estimated by determining what peak ground acceleration enveloped nearly all gas-related fires. The peak ground acceleration bounds were used to identify earthquake ground motion records to examine the spectral content of the ground motions. Six ground motion record locations were selected, three where EGV actuation was considered warranted and three locations without significant building damage or post-earthquake fire. The spectral content of the three ground motion records at the periphery of gas-related fires formed the basis for revising EGV actuation requirements.

The first version of ASCE 25 was approved in 1997 and incorporated several new requirements and limitations:

1. The qualification of EGVs was based upon sinusoidal shaking of the device for two sets of motions with four period-acceleration levels. One set of motions defined shaking levels for which the EGVs must actuate based upon the Northridge earthquake data. The EGV manufacturers participating in the ASCE 25 standard development were concerned that their devices could not meet a tight tolerance on the actuation levels. Therefore, a second set of motions was defined below the must-actuate level. Therefore, EGVs meeting the requirements of ASCE 25 could actuate at a level of ground motion anywhere between these two test levels, referred to and the “must actuate” level and the “must not actuate” level. The test points defining these levels are illustrated in Figure 1.

2. The scope of the standard was defined as wood-frame residential buildings less than three stories high. This building type constituted the majority of the building stock impacted by the Northridge earthquake. However, the standard did not expressly prohibit the use of EGVs qualified to the standard from being applied to other types of structures.

3. The actuation levels in the standard did not include consideration of potential building damage. This was based upon a majority of the standard committee believing that there was little benefit in isolating gas service to a building that would not survive earthquake ground shaking.

4. The typical installation of an EGV is assumed to be immediately downstream of a residential customer's gas meter. The standard required that EGVs be installed at grade on a substantial foundation such that the device would experience ground motions similar to the free-field motions measured in the Northridge earthquake and used to define actuation levels.

There has only been one significant change to ASCE 25 since 1997. The 2006 version of ASCE 25 added an additional set of testing levels well above the levels where the EGV must actuate. This set of test levels was developed to address a concern within the committee that very strong ground shaking might damage the device, preventing it from shutting off gas or reopening once gas service had been shut off.

5.2 Example Impact Areas for EGVs Conforming to ASCE 25-16

The potential impact of universal application of the actuation requirements of ASCE 25-16 was evaluated by considering a hypothetical earthquake scenario consisting of a M_w 6.0 crustal earthquake with an epicenter located in New Westminster beneath the rail yard near the north shore of the Fraser River (latitude 49.2, longitude -122.92). This scenario was selected for two reasons. First, it is a small-to-moderate earthquake with a potential to cause modest amounts of localized liquefaction and lateral spread displacement but unlikely to cause significant structural damage outside of the immediate epicentral area. Second, this level of earthquake could represent an aftershock of a larger earthquake that could retrigger EGVs at locations where gas service had been restored.

The purpose of examining this scenario is to gauge the potential extent of gas service restoration for an earthquake with limited damage potential. This is an important consideration since loss of natural gas service may increase the number of persons requiring temporary shelter because of the lack of fuel for heating and cooking. Loss of natural gas service can close businesses or significantly increase the period of interruption to office buildings, restaurants, manufacturing plants and other facilities. This interruption may lead to the closure of some businesses that provide much-needed services or supplies.

Ground motions were computed using a spreadsheet developed by Dr. Emel Seyhan for computing ground motions using NGA West-2 ground motion prediction equations (Pacific Earthquake Engineering Research Center, 2015). Since the purpose of computing ground motions was to approximately gauge the potential impact on service interruption, several simplifying assumptions were made:

1. The Idriss ground motion prediction equation was not considered, and the remaining four prediction equations were given equal weight.

2. Average shear wave velocity: 450 m/s

3. Style of faulting: Strike-Slip

4. All other parameters were allowed to go to their default values

For simplicity, ground motions were assumed to decay uniformly from the earthquake epicenter. The area where EGV actuation could occur was defined by the distance from the epicenter at which any of the ASCE 25 actuation levels was exceeded. Three cases were examined to assess the area where the scenario earthquake would lead to loss of gas service:

1. An area where the mean ground motion exceeds the must-actuate level.

2. An area where the mean ground motion exceeds the must-not actuate level.

3. The prior two cases used the mean estimate of ground motion. However, ground estimates are highly uncertain. For example, the distance from the epicenter to exceed the 0.4 second must actuate level is 13 km. The distances that correspond to ground motion with a probability of exceeding the mean between 16% and 84% (plus or minus one standard deviation) are 25 km and 5 km, respectively. To get a worse-case estimate, the area was determined corresponding to the must not acuate level and a ground motion with a 16% chance of exceeding the mean.

The areas corresponding to the above cases are illustrated in Figure 4. The number of services impacted was compared against the total number of meters south of Whistler and west of Chilliwack (Figure 5). The results from this exercise are summarized in Table 8. The number of customers that could lose service with EGVs installed that conform to ASCE 25 for the scenario earthquake ranges from a little over 98,000 to a little over 550,000 which is 13% to 71% of the customers south of Whistler and west of Chilliwack.

To give some context to the numbers in Table 8, it is instructive to review service restoration efforts required in past earthquakes. Restoring gas service involves four general steps:

1. Inspect all gas appliances, appliance connections, and appliance vents for signs of physical damage.

2. Turn off gas to all gas appliances at the houseline valve connection.

3. Turn on gas service to the structure and confirm that no gas is flowing. Flowing gas indicates a leak in the gas piping within the structure and service cannot be restored.

4. If no gas is flowing with the appliances isolated, gas can be turned on to all gas appliances.

While some homeowners are capable of performing these tasks, most are not. If these tasks are not performed correctly, the potential for gas leakage and eventual ignition of carbon monoxide poisoning remains. Typically, a homeowner will request assistance with gas service restoration from the gas utility or a private contractor and be available to allow access to the structure to inspect gas appliances and vents. In multi-unit residential housing where a single gas meter may be used for the entire building, these tasks would require access to all units to access gas appliances and the time to implement gas service restoration could be significantly extended if all units cannot be accessed.

5.3 Potential Duration of Service Outage for Hypothetical Earthquake Scenario

The length of gas service interruption for the hypothetical earthquake scenario will depend upon the number of personnel that can be mobilized from within and outside of FEI to respond following the earthquake. Information on gas service restoration timelines is largely limited to data available from three moderate to large earthquakes that impacted urban areas in California, namely the 1987 Whittier Narrows, 1989 Loma Prieta, and 1994 Northridge earthquakes.

SoCalGas operates the natural gas distribution system in the region impacted by the Whittier Narrows earthquake. Approximately 20,600 customer calls for service restoration were received, of which about 16,500 were the result of customers shutting off their own gas service in response to media safety announcements immediately following the earthquake. Service was restored within 10 days by Southern California Gas Company personnel working 10-hour days.

PG&E provides natural gas and electric service to the regions affected by the Loma Prieta earthquake. Three service areas were isolated from the rest of the system due to considerable earthquake damage. Approximately 160,000 gas customers were without gas service following the earthquake, mostly due to customers shutting off their own service in response to media safety announcements immediately after the earthquake. Over a period of nine days, personnel from Pacific Gas and Electric Company and six neighboring utilities and contract plumbers restored service to more than 156,000 individual customers. From these teams, an average of 1,000 personnel worked during five of the days.

The total number of customers left without service immediately after the Northridge earthquake main shock and subsequent aftershocks exceeded 150,000, with approximately 133,000 of the service interruptions initiated by customers as a precautionary measure. SoCalGas is the gas service provider in the region severely affected by the Northridge earthquake. More than 3,400 employees, 420 provided by other California gas utilities as part of mutual assistance agreements, were mobilized to restore gas service. Service was restored to approximately 120,000 customers within 12 days.

Variation in restoration time is a function of the number of outages, the size of the service area experiencing service interruption, the quantity of personnel and equipment mobilized to restore service, and logistical difficulties caused by other earthquake damage such as road closures. Considering the experience in the Northridge and Loma Prieta earthquakes, the rate of service restorations within the PG&E and SoCalGas service regions is likely to vary between 10,000 and 20,000 per day (ASCE, 2002).

Restoration rates can also be approximated using information on the number of customers restored, the number of personnel deployed, and the time to restore service. Based upon the Northridge restoration information, the restoration rate is approximately three service restorations per restorer per day. Based upon information in McDonough (1997), the restoration for Mountain Fuel employees was approximately 9 restorations per day. An upper-bound rate can be estimated assuming that 1,000 personnel were working for nine days to restore service following the Loma Prieta earthquake instead of the five days where the average number of personnel was 1,000. With this assumption the restoration rate is 17 per restorer per day.

FEI currently employs approximately 160 personnel that could be available to restore gas service. Additional support in restoring service could be provided by gas fitters in the region. It is unknown how many plumbers or other private entities could assist in service restoration. The FEI website of approved contractors lists approximately 155 contractors providing gas fitting services in the Vancouver area. For the purposes of estimating service restoration times, it is assumed that the total number of available restoration personnel is 350 and the restoration rate is optimistically assumed to be 10 restorations per person per day. The resulting restoration time for the hypothetical earthquake scenario could range from 4 to 23 weeks. This estimate does not include the likely need to restore service more than once in the event of earthquake aftershocks. Of course, this outage duration could be shortened if resources are available from gas utilities outside of the impacted area (e.g., BC Interior, Washington, Oregon, Alberta). However, it is evident that the time to restore service can easily be several months.

The hypothetical scenario is only meant to illustrate an order of magnitude estimate of the gas service outage from a small to moderate earthquake that could occur if every customer had an EGV installed. An outage lasting a month or more could have serious impacts on customers, especially customers in multi-unit residential housing and especially if the outage occurred during the winter month. Natural gas used for space heating in approximately 40% to a little over 75% of mid-rise to high-rise multi-unit residential buildings in the Vancouver and Victoria region (Finch et al., 2010). In addition, natural gas is a key resource for certain manufacturing activities and nearly all commercial cooking relies upon natural gas. In the event of a much larger earthquake where many people would need assistance because of damage to their homes, the ability to provide sufficient emergency shelter could be adversely impacted by the loss of gas for heating and cooking and an increase in persons without damaged homes needing temporary shelter because of a similar lack of gas for heating and cooking.

6 CUSTOMER ACTIONS TO IMPROVE NATURAL GAS SAFETY

The ability to shut off gas service remotely or if an excess-flow condition exists once the AMI project is implemented will provide increase safety in the event of significant damage to a customer's gas system and provide a means to mitigate gas service from becoming a potential hazard (shutting of service to multi-residential housing units in the event of a fire). There are several measures that can be implemented by gas customers to provide enhanced gas safety beyond the excess-flow and remotely operated shut off capabilities planned for the AMI project.

Customers can install excess flow valves on the piping or tubing connecting the gas appliance to the houseline. These inexpensive devices are designed with different flow rates to accommodate the amount of gas consumed by the gas appliance. If the event the piping or tubing connected to the gas appliance is damaged to the point that a large leak occurs, the excess flow valve will shut off gas from the houseline.

Gas appliances should be restrained to prevent them from sliding or tipping over as a result of earthquake shaking. This is already required for all new gas-fired tank water heaters. Gas furnaces and free-standing gas ovens and ranges should similarly be restrained. As an earthquake preparedness measure, restraint of electric tank water heaters should be considered to preserve the water in the tank in the likely event normal water service can be impacted by an earthquake.

Installation of methane detectors and carbon monoxide detectors can alert building occupants to houseline and vent damage that may not be evident.

Building owners can supplement the earthquake safety measures of the AMI project by installing control systems that can sense natural gas leakage in the vicinity of multiple gas appliances and automatically shut off the gas at the main if a gas leak is detected. Wireless systems are commercially available with several options including shutting off gas service upon detection of carbon monoxide and shutting of water service if a leak is detected.

7 CONCLUSIONS

This report has identified the following points that support a conclusion that if a utility gas smart meter were to be available with an EGV option, it would not provide a significant reduction in life-safety risk or post-earthquake fire ignitions.

1. The safety risk to individuals in single family homes from earthquake-triggered fires, regardless of cause, is low because several evacuation paths through doors or windows are typically available. For these individuals, the impact of earthquake-triggered fires is largely financial with fire losses covered by home insurance policies.

2. The life-safety risk from earthquake-triggered fires for occupants of multi-unit residential buildings can be much greater if the building suffers significant earthquake damage that can block corridors and stairwells or otherwise trap occupants.

3. Natural gas appliances have historically been a contributing factor in 15% to 50% of post-earthquake fires. This is based upon data from earthquakes in California between 1987 and 1994. The contribution of gas appliances to post-earthquake fire ignitions is likely much lower today because of the elimination of live pilot lights in modern gas appliances. Therefore, improvements in personal safety from widespread installation of EGVs is considered marginal.

4. The risk of damage to natural gas appliances is reduced from what may have existed 10 to 20 years ago because of the requirement to secure gas appliances, to prevent shifting during earthquakes, and the use of flexible gas connections.

5. The ability of a natural gas appliance to be a source of post-earthquake fire ignition is dependent upon some combustible material or vapor coming into contact with a gas flame. An EGV does not prevent this type of ignition if it occurs during or several minutes after earthquake ground shaking.

Ideally, shutting off gas service should occur when there is significant physical damage to gas appliances in interior gas piping. The excessive flow feature that will be incorporated into the AMI project will meet this goal. Because it is not possible to define EGV actuation levels based upon the likelihood of damage to structures and components of customers gas systems, EGV actuation levels must be biased to the low side. For the case of universal EGV installation, there is a high likelihood for widespread isolation of service when there is a low likelihood of any damage.

Therefore, in addition to having minimal benefit in terms of improved safety and reduced fire ignitions, universal installation of EGVs on all gas services could have serious detrimental impacts in the event service is needlessly interrupted over a large part of the FEI Lower Mainland service territory. A modest earthquake with limited potential for structural damage could result in the automatic shut off of gas service to more than 100,000 customers for up to several months, increasing demands for temporary shelter and creating substantial business interruption losses.

8 REFERENCES

1. ABC7, 2019, https://abc7.com/earthquake-usgs-mojave-desert-california/5378574/, [last accessed April 18, 2021].
2. American Society of Civil Engineers, 2016, *Earthquake Actuated Automatic Gas Shutoff Devices*, ASCE Standard 25-16, Reston, Virginia.
3. American Society of Civil Engineers, 2012, *Christchurch, New Zealand Earthquake Sequence of M_w 7.1 September 04, 2010, M_w 6.3 February 22, 2011, M_w 6.0 June 13, 2011: Lifeline Performance*, Technical Council on Lifeline Earthquake Engineering Monograph No. 40, Eidinger, J., and Tang, A. (eds.), Rev. 0, 345pgs.
4. American Society of Civil Engineers, 2002, Improving Natural Gas Safety in Earthquakes, report to the California Seismic Safety Commission prepared by the ASCE 25 Task Committee on Earthquake Safety Issues for Gas Systems, March 18.
5. Applied Technology Council, 2007, *Recommended Requirements for Automatic Natural Gas Shutoff Valves in Italy*, ATC-74, Redwood City, California, 88 pgs.
6. California Seismic Safety Commission, 2002, *Natural Gas Safety in Earthquakes*, https://ssc.ca.gov/wp-content/uploads/sites/9/2020/08/cssc_2002-03_natural_gas_safety.pdf, [last accessed April 15, 2021].
7. Finch, G., Burnett, E., and Knowls, W., 2010, "Energy Consumption in Mid and High Rise Residential Buildings in British Columbia," Proceedings of the Second Building Enclosure Science and Technology Conference, https://cdn.ymaws.com/www.nibs.org/resource/resmgr/BEST/BEST2_002_EE3-1.pdf, [last accessed April 16, 2021].
8. Geological Survey of Canada, 2021, "Earthquakes in southwest British Columbia," Geofacts, https://www.seismescanada.rncan.gc.ca/pprs-pprp/pubs/GF-GI/GEOFACT_earthquakes-SW-BC_e.pdf, [last accessed April 23, 2021].
9. Honegger, D.G., 1995, *Automatic Gas Shutoff Device Actuation Requirements Based on Damage in the January 17, 1994 Northridge Earthquake*, EQE International Report 52316.01 to the American Society of Civil Engineers, October.
10. Honegger, D.G., 1997, "Translating Earthquake Damage Data Into New Performance Requirements for Earthquake Actuated Automatic Gas Shutoff Devices in the United States," *Proceedings of the 7th U.S.-Japan Workshop on Earthquake Disaster Prevention for Lifeline Systems*, D. Ballantyne (ed.), EQE International.
11. McDonough, P. 1997, "Residential Natural Gas Piping and Appliances", *The Loma Prieta, California Earthquake of October 17, 1989: Lifelines, Schiff*, A. (ed.), U.S. Geological Survey Professional Paper 1552-A.
12. Kolaj, M., Adams, J, and Halchuk, S., 2020, "The 6th Generation Seismic Hazard Model of Canada," *Proceedings of the 17th World Conference on Earthquake Engineering*.
13. McGillivray, G., 2021, "Earthquakes are an existential threat to B.C.'s Lower Mainland-but we can defend ourselves now," Globe and Mail Opinion, April 5.
14. Pacific Earthquake Engineering Research Center, 2015, NGAW2_GMPE_Spreadsheets_v5.7_041415.xlsm, https://apps.peer.berkeley.edu/ngawest2/wp-content/uploads/2016/02/NGAW2_GMPE_Spreadsheets_v5.7_041415_ProtectedLocked.xlsm, [last accessed April 13, 2021].
15. Scawthorn, C.G., 1985, "Post-Earthquake Fire", *Proceedings of the U.S.-Japan Workshop on Urban Earthquake Hazard Reduction*, Publication No. 85-03, EERI, Berkeley, CA, pgs. 237-243.

16. Scawthorn, C.G., 1986, "Simulation Modeling of Fire Following Earthquake", *Proceedings of the Third U.S. National Conference on Earthquake Engineering*, Vol. III.

17. Scawthorn, C.G., 1987, *Fire Following Earthquake: Estimates of the Conflagration Risk to Insured Property in Greater Los Angeles and San Francisco*, All-Industry Research Advisory Council, Oak Brook, IL.

18. Structural Engineers Association of B.C. (SEABC), *British Columbia Earthquake Fact-Sheet*, https://www.egbc.ca/getmedia/4278c069-0374-4cc2-9e73-2b454a0f978a/SEABC-Eathquake-Fact-Sheet.pdf.aspx [last accessed April 12, 2021].

19. VC Star, 2019, https://www.vcstar.com/story/news/2019/07/05/california-earthquake-ridgecrest-what-we-know-kern-county-aftershock-foreshock/1663088001/, [last accessed April 18, 2021].

20. Williamson, R.B. and Groner, N., 2000, *Ignition of Fires Following Earthquakes Associated with Natural Gas and Electric Distribution Systems*, Pacific Earthquake Engineering Research Center, University of California at Berkeley.

Table 1: Summary of Fires in the Loma Prieta Earthquake

Area	Earthquake Fire Ignitions
San Francisco (Oct. 17-19)	31
Berkeley	1
Santa Cruz County	20
Watsonville	3
Santa Clara County	1
Nisene Marks State Park	1

Table 2: Causes of Fire Ignitions in San Francisco from the Loma Prieta Earthquake

Cause	Number	% of Total
Electrical Wiring	6	19
Electrical Equipment	8	26
Stove (gas or electric)	9	29
Water Heater	1	3
Other Gas Appliance	2	6
Gas Explosion	1	3
Miscellaneous	4	13
Unknown	1	3

Table 3: Northridge Earthquake Fire Statistics for Structures on January 17, 1994 (from ATC, 2007)

Fire Department	Earthquake Fire Ignitions	Gas-Related Earthquake Fire Ignitions
Beverly Hills	0	0
Burbank	0	0
City of Los Angeles	77	38
Costa Mesa	0	0
Covina	1	0
Glendale	0	0
El Monte	1	0
Fillmore	2	1
Glendale	0	0
Inglewood	1	0
Long Beach	1	0
Newport Beach	0	0
Pasadena	1	Not reported
Santa Monica	10	6
Santa Paula	0	0
South Pasadena	0	0
Los Angeles County	15	6
Ventura County	10	3
TOTAL	110	54

Table 4: Summary of Building Fire Ignitions for Recent Earthquakes (from ATC, 2007)

Earthquake	Magnitude	Earthquake Fire Ignitions	Gas-related Fire Ignitions
1964 Alaska	9.2	4-7	0
1965 Puget Sound	6.7	1	Not Available
1971 San Fernando	6.6	109	15
1983 Coalinga	6.2	1-4	1
1984 Morgan Hill	6.2	3-6	1
1986 Palm Springs	6.2	3	0
1987 Whittier	5.9	6	3
1989 Loma Prieta	7.2	67	16
1994 Northridge	6.7	97	54

Table 5: Fire Ignitions for the 13 Days Following the Christchurch M7.1 Main Shock (From TCLEE, 2002)

Date and Time	Adress	Event Cause
Sept. 4, 2010-05:03 am	Moorhouse Ave.	Electrical component failure – earthquake
Sept. 4, 2010-12:11 pm	Royleen St.	Heat source close to combustibles
Sept. 4, 2010-08:33 am	Thurlestone Pl.	Chimney fire (cracked / damaged chimney)
Sept. 4, 2010-19:17 pm	Hoonhay Rd.	Chimney Fire
Sept. 5, 2010-10:30 am	Raxworthy St.	Fallen Heater
Sept. 8, 2010-07:47 am	Moorhouse Ave.	Electrical component failure
Sept. 9, 2010-03:49 am	Worchester Blvd.	Suspicious
Sept. 16, 2010-04:14 am	O'Briens Rd.	Water cylinder moved, worn insulation

Table 6: Summary of Repairs by Southern California Gas Company Following the Whittier Narrows Earthquake

Damage	Number	% of Total
Appliance: Vent	40	2
Appliance: Miscellaneous	134	7
Appliance Connector: Range	90	5
Appliance Connector: Water Heater	385	20
Appliance Connector: Furnace	127	7
Appliance Connector: Dryer	46	2
Appliance Connector: Miscellaneous	97	5
Piping: Meter Set Assembly	376	20
Piping: Houseline	505	26
Piping: Yardline	120	6
TOTAL	1,920	100

Table 7: Summary of Mountain Fuel Personnel Loma Prieta Questionnaire Responses

Type of Damage	Percentage of Observations		
	Los Gatos	Cupertino	Mountain View
Water Heater	44	38	41
Vent Piping	58	67	57
Furnaces	13	15	11
Ranges	1	<1	<1
Outdoor Meter Sets	5	4	4
Interior Piping	4	7	9
Evidence of Fire	<1	1	0

Table 8: Number of Meters Actuated for Hypothetical M_w 6.0 Earthquake in New Westminster

EGV Actuation Level (see Figure 3)	Ground Motion Level	Epicentral Distance (km)	Number of Meters Actuated	Fraction of Meters in Figure 4 Region Actuated
Must Actuate	Mean Estimate	13	98,529	13
Must Not Actuate	Mean Estimate	26	332,234	43
Must Not Actuate	16% Chance of Higher Motion	64	551,304	71

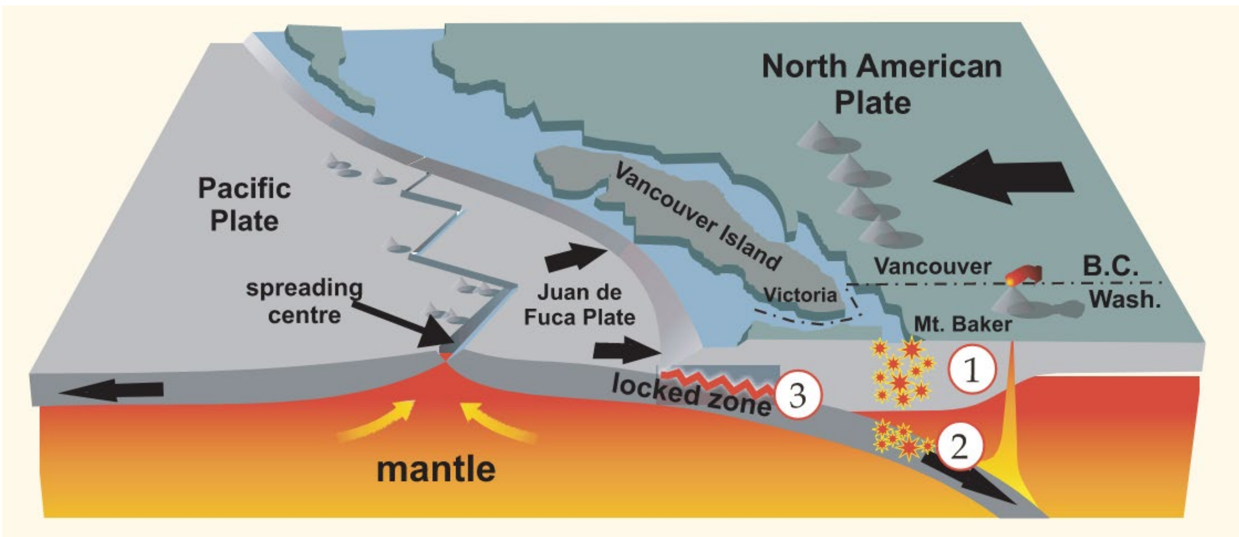
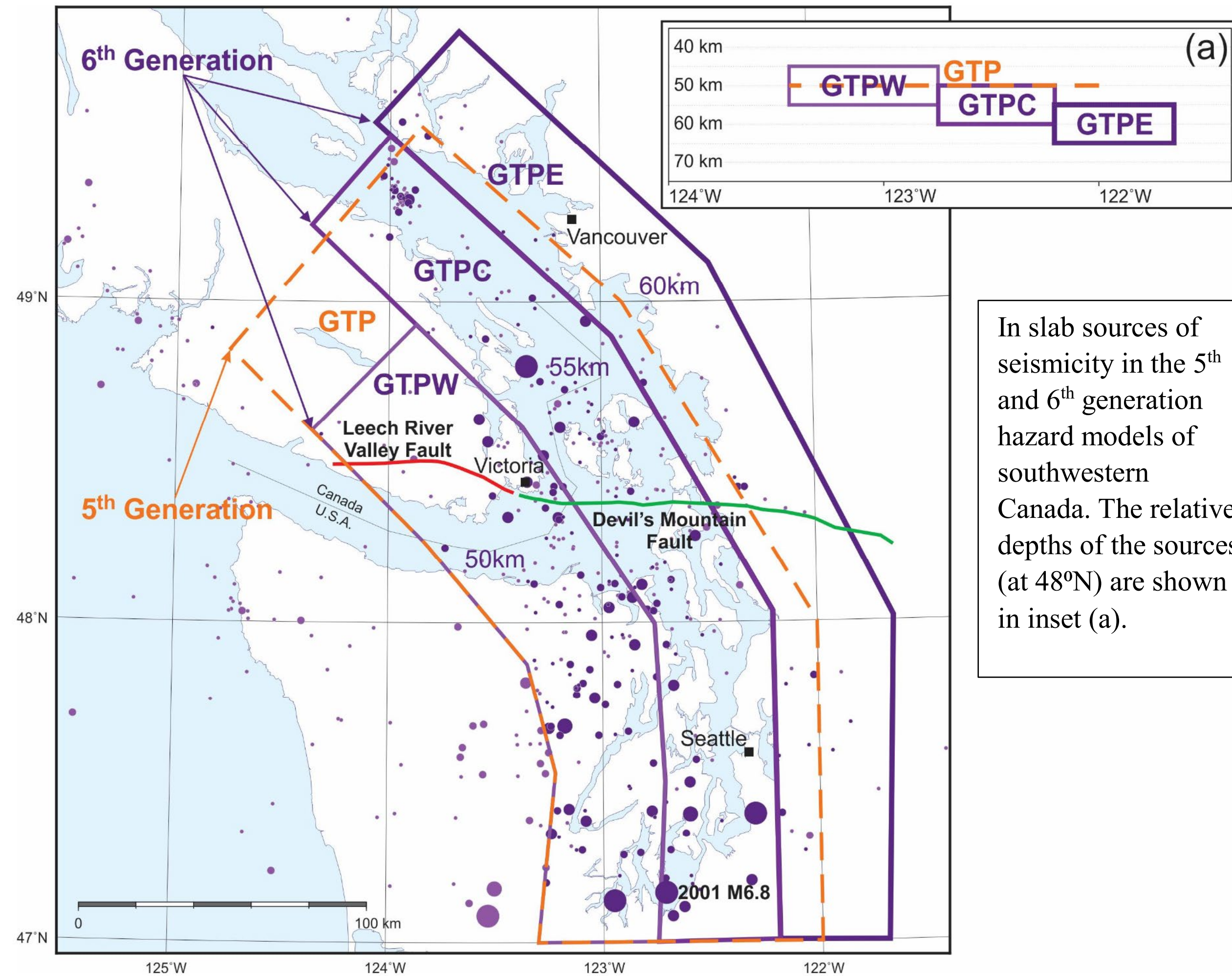


Figure 1: Sources of Earthquakes in Southwest British Columbia (from GSC, 2021)

[North American crustal earthquakes (1), Juan de Fuca in-slab earthquakes (2), subduction earthquakes (3)]



In slab sources of seismicity in the 5th and 6th generation hazard models of southwestern Canada. The relative depths of the sources (at 48ºN) are shown in inset (a).

Figure 2: In-Slab Earthquake Sources in 6th Generation Seismic Hazard Model (from Kolaj et al., 2020)

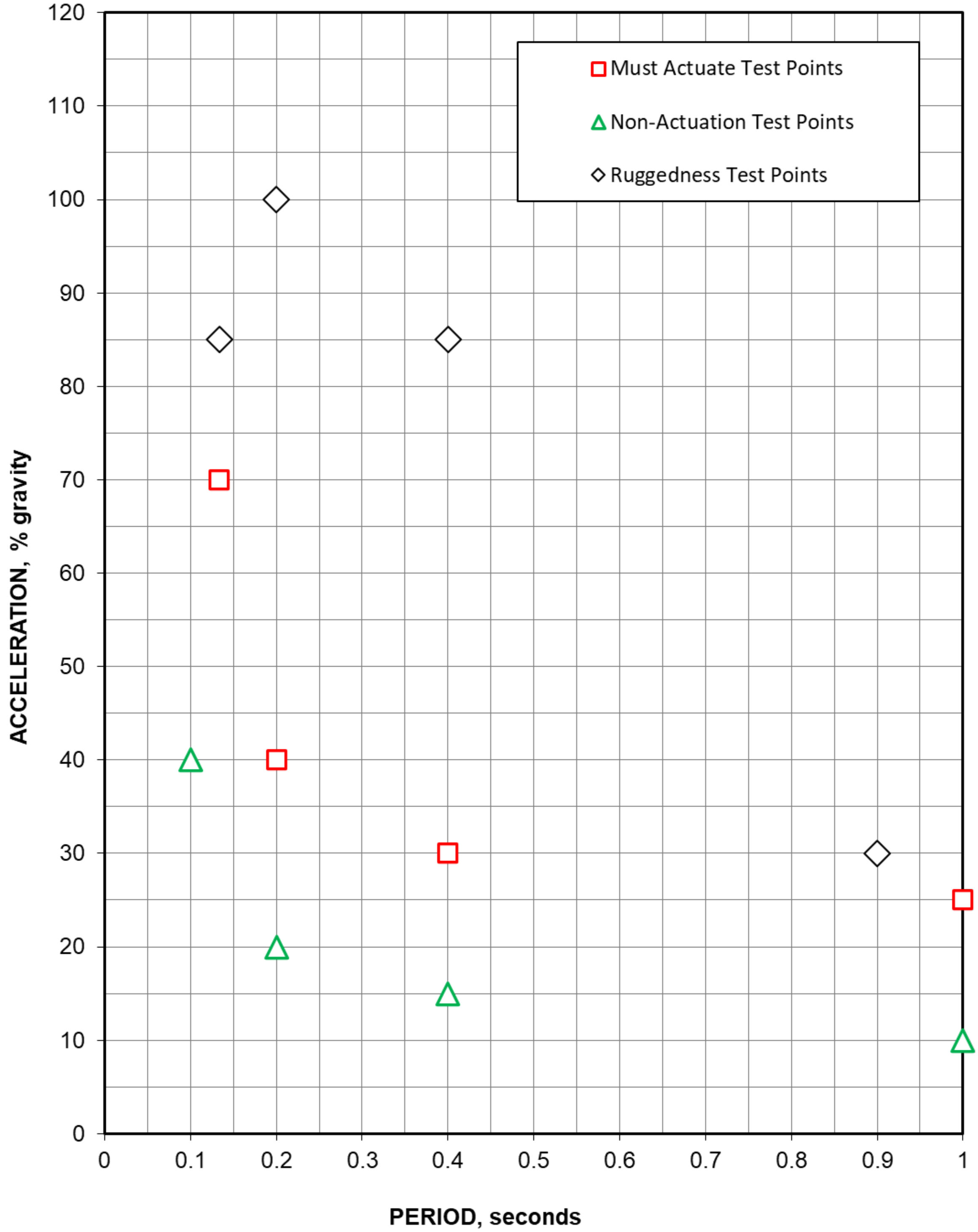


Figure 3: ASCE 25-16 EGV Qualification Test Levels

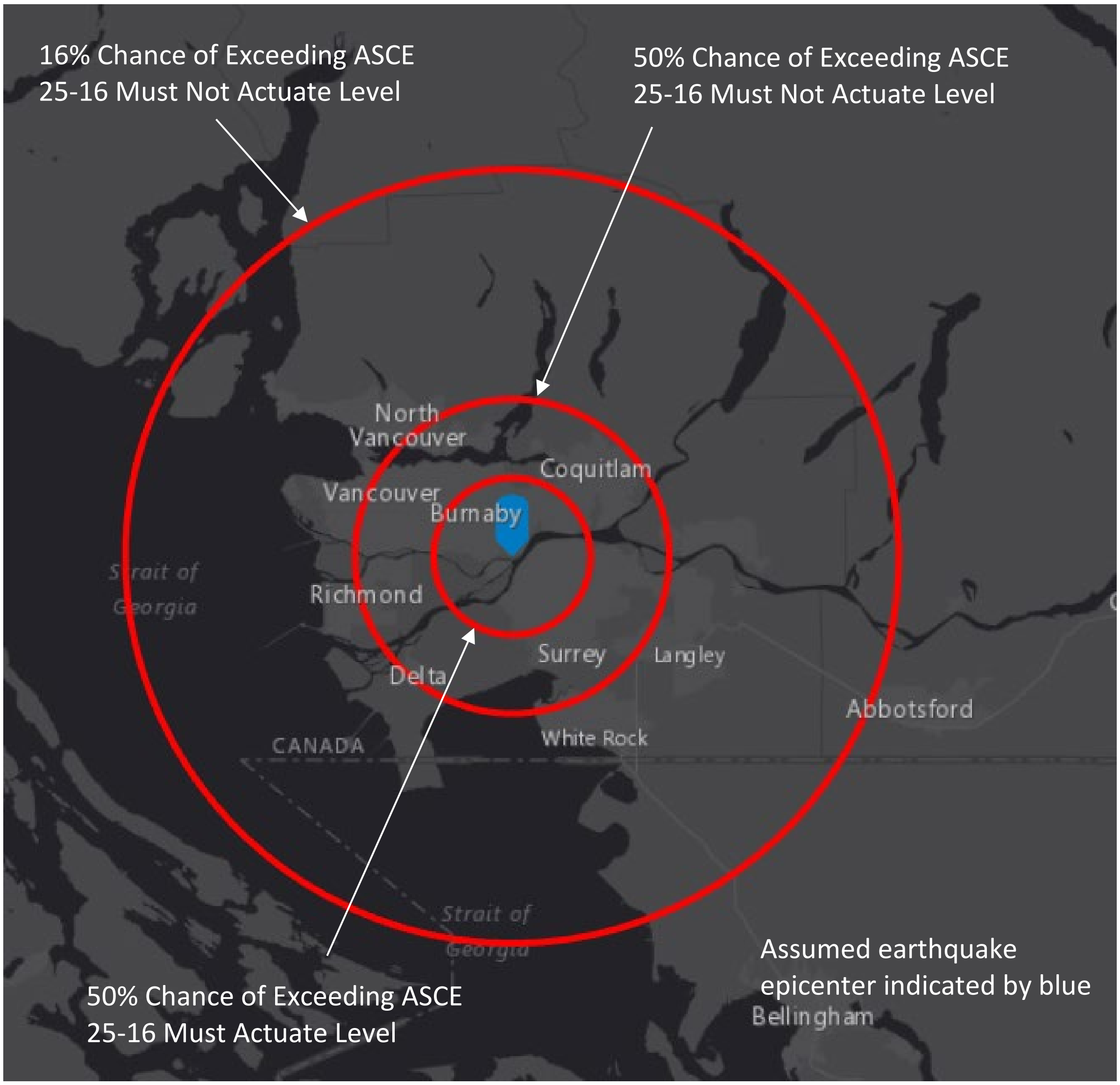


Figure 4:Extents of EGV Actuation for Hypothetical M_w 6.0 Earthquake in New Westminster

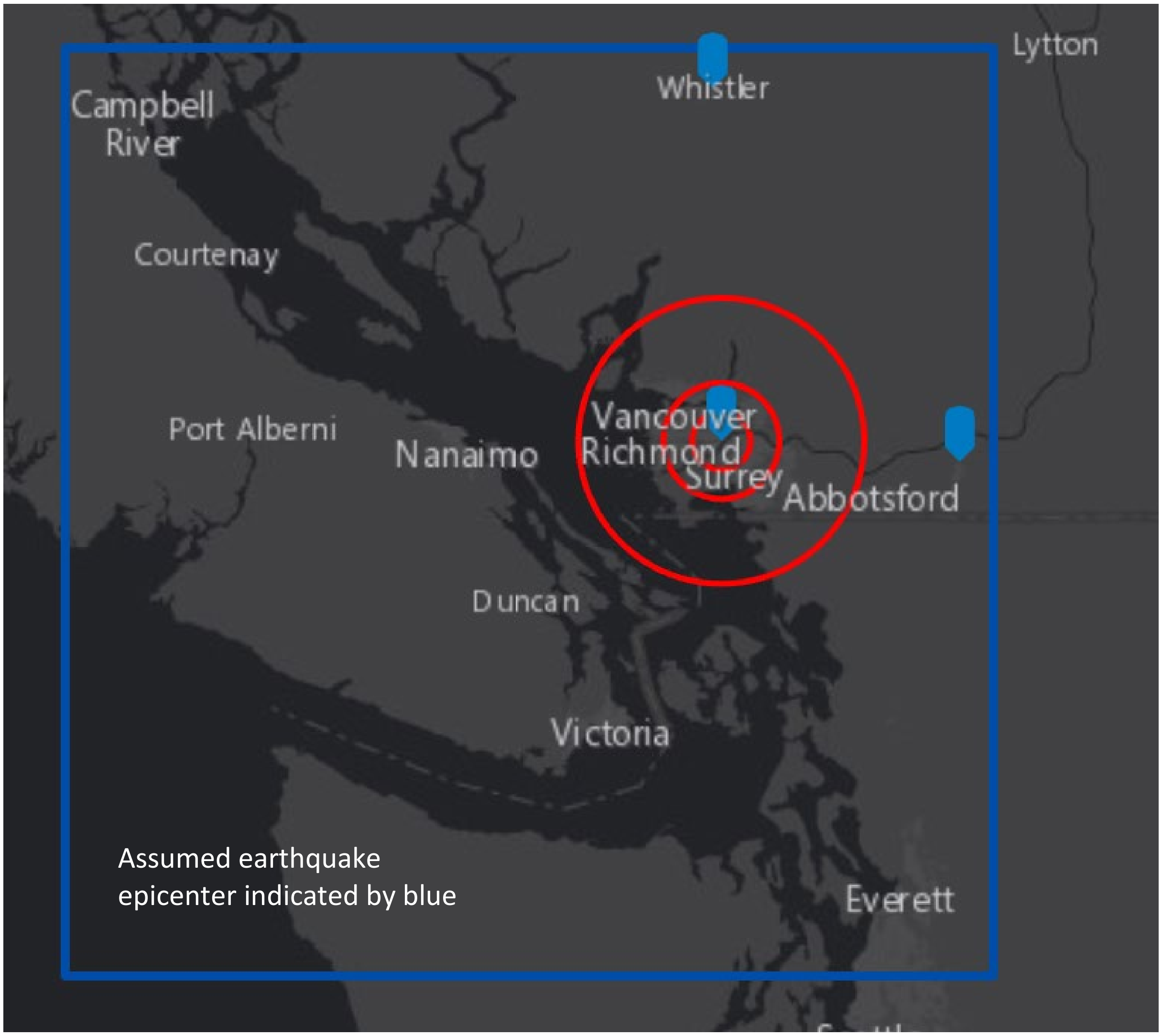


Figure 5: FEI Customer Service Area Used to Determine Fraction of Customers Impacted by Hypothetical Earthquake Scenario

ATTACHMENT 1: STATE OF CALIFORNIA INFORMATION BULLETIN 2005-02

STATE OF CALIFORNIA - BUSINESS, TRANSPORTATION AND HOUSING AGENCY Arnold Schwarzenegger, Governor

DEPARTMENT OF HOUSING AND COMMUNITY DEVELOPMENT
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March 21, 2005

INFORMATION BULLETIN 2005-02 (SHL)

TO: **City and County Building Officials**
Interested Parties (SHL)
Division Staff

SUBJECT: **AUTOMATIC GAS SHUTOFF DEVICES**

The purpose of this Information Bulletin is to provide information regarding automatic gas shutoff devices meeting the requirements of Title 24, Part 12, Standards 12-16-1 and 12-16-2, for seismic gas shutoff and excess flow gas shutoff devices respectively.

Senate Bill 1992 (Chapter 1051, Statutes of 2002) amended Section 19201 and added Section 19205 to the Health and Safety Code. These sections require the Department of Housing and Community Development (Department), in consultation with the Division of the State Architect (DSA) and the Office of the State Fire Marshal (SFM), to consider whether or not to propose building standards mandating the installation of seismic gas shutoff devices and/or excess flow gas shutoff devices in all or a portion of dwelling units, motels, hotels and lodginghouses throughout the state.

After careful consideration of all currently available information, including a study commissioned by a manufacturer of excess flow valves, the Department concluded that there was insufficient evidence to support a statewide requirement for the installation of seismic gas shutoff devices and/or excess flow gas shutoff devices. The Department recognizes; however, some jurisdictions, particularly those in seismically active regions of the state, may wish require the usage of such devices. The following information is provided to assist local governments that may want to consider mandating these type devices through enactment of local ordinances.

Two Types of Automatic Gas Shutoff Devices

The stated purpose for considering the installation of seismic gas shutoff devices and/or excess flow gas shutoff devices is to enhance safety and provide additional protection for residential occupants and first responders from unnecessary threats of injury or death and to reduce property damage from some residential gas pipeline failures that may result in a fire.

The following definitions apply to seismic gas shutoff devices and/or excess flow gas shutoff devices that are the subject of this Information Bulletin and which under current California law must be certified by the Division of the State Architect prior to sale and installation in a gas piping system.

<u>Seismic Gas Shutoff Device:</u> Means an earthquake-sensitive gas shutoff device intended to prevent gas flow in a gas piping line following a specified degree of seismic disturbance.

Generally, a single seismic gas shutoff device would be installed in a residential occupancy's gas piping system. This device normally is installed in the main gas line down-stream from the utility company's gas meter and service tee on the outside of the building. It is designed to activate only in cases when building shaking may be sufficient to cause damage to the gas piping system. Some require installation with a bracing device.

<u>Excess Flow Gas Shutoff Device</u>: Means a device or system designed to automatically shut off gas flow in a piping system in the event of significant overpressure surge or rupture of the gas supply line down-stream of the device or system.

Individual excess flow gas shutoff devices generally are installed at each appliance outlet between the gas piping system and the appliance connector. In addition, a main excess flow gas shutoff device is installed in the main gas line down-stream from the meter and service tee. The purpose of these devices is to shut off the flow of gas to individual appliances or the entire system when the flow of gas through the device is increased beyond its predetermined operating flow rate.

The operation of the device depends on the ability of a given piping system to generate the required excess gas flow. These valves will function on most incidents of catastrophic pipe breakage.

The following table, extracted from the California Seismic Safety Commission's report, *Improving Natural Gas Safety in Earthquakes*, provides a comparison of the general benefits and drawbacks for seismic gas shutoff devices, excess flow gas shutoff devices, and the currently required manual gas shutoff valve.

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	Manual Shutoff Valve And Wrench	Seismic Gas Shutoff Device	Excess Flow Gas Shutoff Device
Basis of Operation	Utilities have installed manual shutoff valves near gas meters allowing owners with proper wrenches to shut off gas in emergencies.	Senses shaking in a building that is above a design level of shaking and automatically shuts off gas.	Senses gas flows that are above a design shutoff flow rate and automatically shuts off gas.
Benefits	All gas services already have valves installed. Guidance for occupants is currently provided in many public information documents like the telephone book.	Activates only in cases when building shaking may be sufficient to cause damage to the gas system. Someone does not need to be present to ensure shutoff.	Activates only in cases when excess gas flows downstream of the device. Someone does not need to be present to ensure shutoff.
Drawbacks	Only effective if someone is present, knows the valve location, has access to the valve, and has a wrench suitable to close the valve.	Can activate even if damage and hazards do not exist. Aftershocks can cause the device to activate after service has been restored. May activate from shaking not related to earthquakes.	Will not shut off gas if leakage is below the design shutoff flow rate, even if a slow leak exists. May not activate if the occupant changes gas systems downstream without modifying the device.

As discussed above, there are two types of automatic shutoff devices, the seismic gas shutoff and the excess flow gas shutoff devices. It is important to emphasize that these devices function differently and have different installation requirements based on the type of device installed. It is just as important to note that manufacturers of the same types of device may have different installation requirements as well. Any device installed within a gas piping system must be installed in accordance with the manufacturer's installation instructions.

For example, some seismic and excess flow gas shutoff devices are required to be installed in the vertical position while others are required to be installed in the horizontal position, and still some may be installed in either position. Some manufacturers of excess flow gas shutoff devices indicate that, to ensure maximum protection and valve performance, a valve should be installed at each appliance as well as at the meter. Additionally, these devices are manufactured for high, medium, and low pressure piping systems, and have a number of flow settings.

It is important to know which type of device is being proposed for installation and who manufactures the device in order to determine the proper installation requirements, and to perform an adequate inspection of the installation. If these devices are not installed correctly, they can fail to function as designed or intended.

Local Ordinances

Local government authorities have a responsibility to consider the impacts of earthquakes in municipal decisions related to building construction methods and materials, building density, the existing built environment, capacity of fire protection services, and traffic management within the local community.

The Department recognizes local government's responsibility to determine if and when unique measures are needed to mitigate the impact of seismic events, floods, and/or other natural disasters. Among mitigation measures that may be considered by local governments is mandating the installation of seismic gas shutoff devices or excess flow gas shutoff valves in residential gas piping systems.

Pursuant to Health and Safety Code Section 17958.5, city and county local ordinances may make reasonably necessary modifications to state residential building standards based on local topographical, geological, or climatic conditions. The Department is aware that a number of jurisdictions in California have local ordinances mandating the installation of seismic gas shutoff valves or excess flow gas shutoff devices. To HCD's knowledge, each community that has adopted such an ordinance is located in "Seismic Zone IV" as identified in the 2001 California Building Code. This zone is considered by most scientists and geologists studying earthquakes to be a likely area in California to experience a major seismic event.

Mandating installation of one of the types of shutoff devices may be accomplished through enactment of a local ordinance to amend the California Building Standards Code based on local topographical, geological, or climatic conditions. The local jurisdiction is required to make an express finding that such modifications or changes to the state building standards are reasonably necessary because local conditions so warrant. The ordinance is required to be filed with the California Building Standards Commission in order for the ordinance to be lawfully enforced.

Questions concerning this Information Bulletin should be directed to the Department's State Housing Law Program staff at the address listed above or by telephone at
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