Summary of the Events at the Fukushima Daiichi Nuclear Plant

And Dominion's Response

April 2011

Dominion

The scenes from Japan depict a terrible tragedy. The destruction and devastation caused by the earthquake and tsunami are shocking. The loss of life is unimaginable. We at Dominion send our thoughts and prayers to everyone affected by this tragedy.

Nuclear Energy in Japan

- 54 nuclear reactors (49 gigawatts)
- Nuclear power supplies ~30% of Japan's electricity
- Two nuclear units under construction
- Tokyo Electric Power Co. produces 27% of Japan's electricity
- 12,000 MW of nuclear energy capacity shut down as a result of the earthquake and tsunami

Fukushima Daiichi Nuclear Station

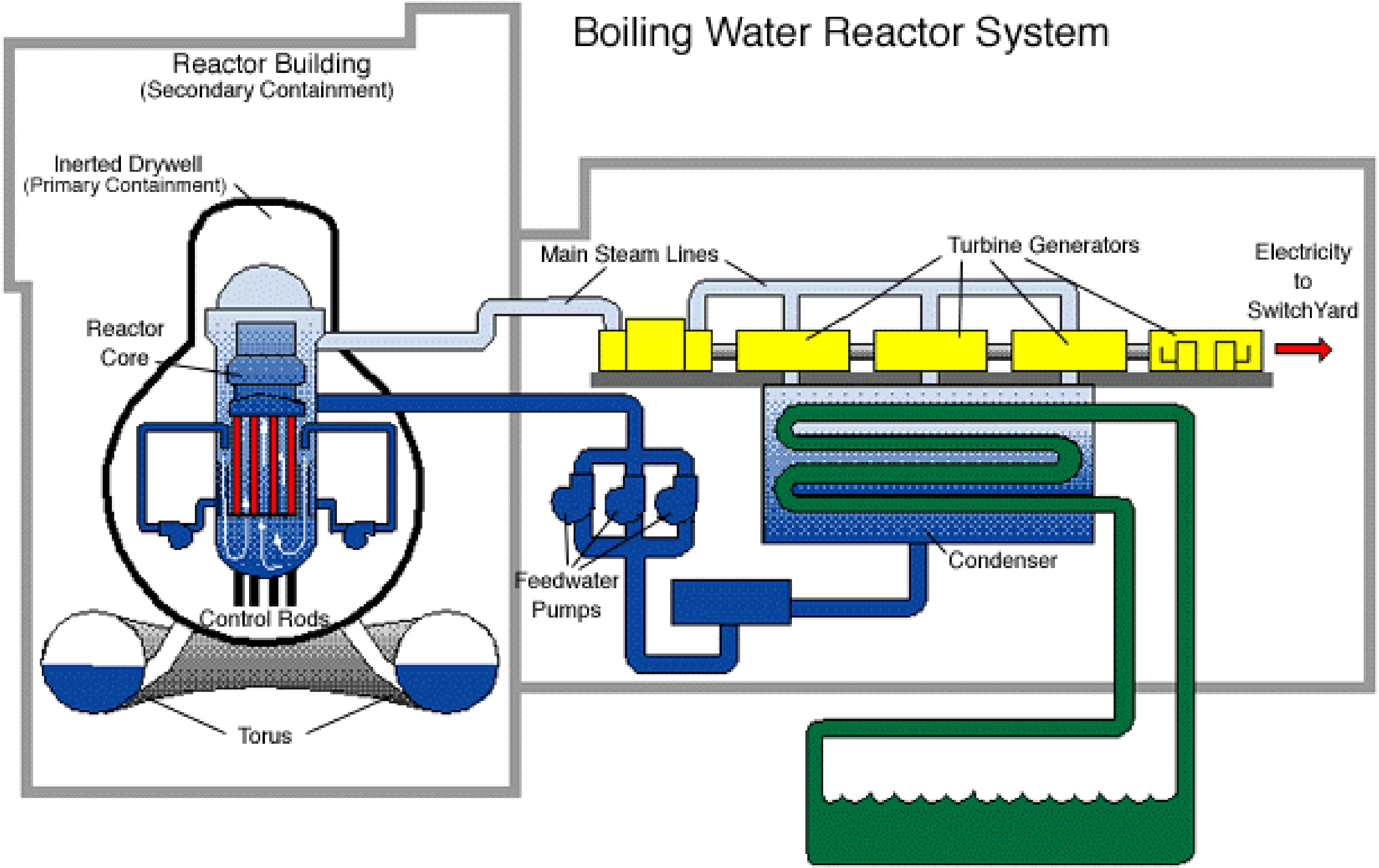
- Unit 1: 439 MWe BWR, 1971
- Unit 2: 760 MWe BWR, 1974
- Unit 3: 760 MWe BWR, 1976
- Unit 4: 760 MWe BWR, 1978
- Unit 5: 760 MWe BWR, 1978
- Unit 6: 1067 MWe BWR, 1979

AT THE TIME OF THE EVENT

- Units 1,2,3 were in operation
- Units 4,5,6 were shutdown for maintenance, inspection, and refueling

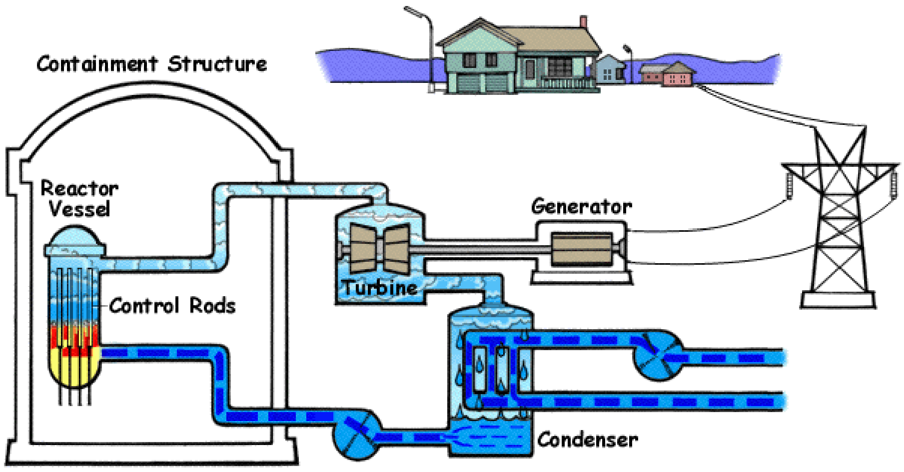
Boiling Water Reactor Design

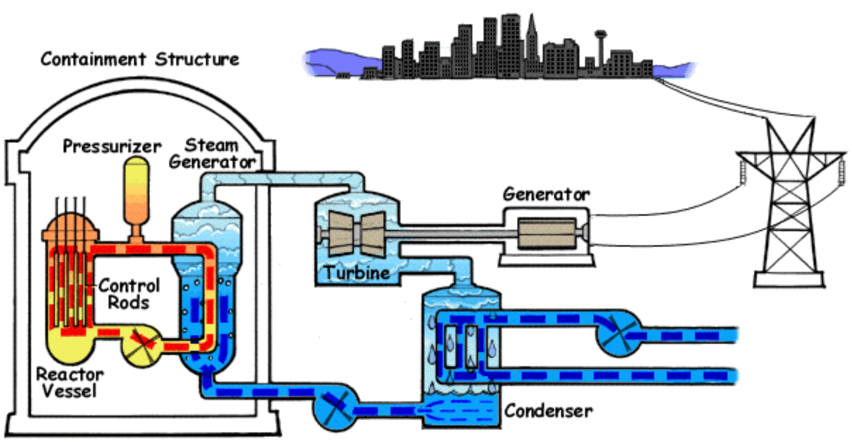
Simplified Schematic of the Fukushima Reactors



Boiling Water Reactor (BWR) versus a Pressurized Water Reactor (PWR) Design

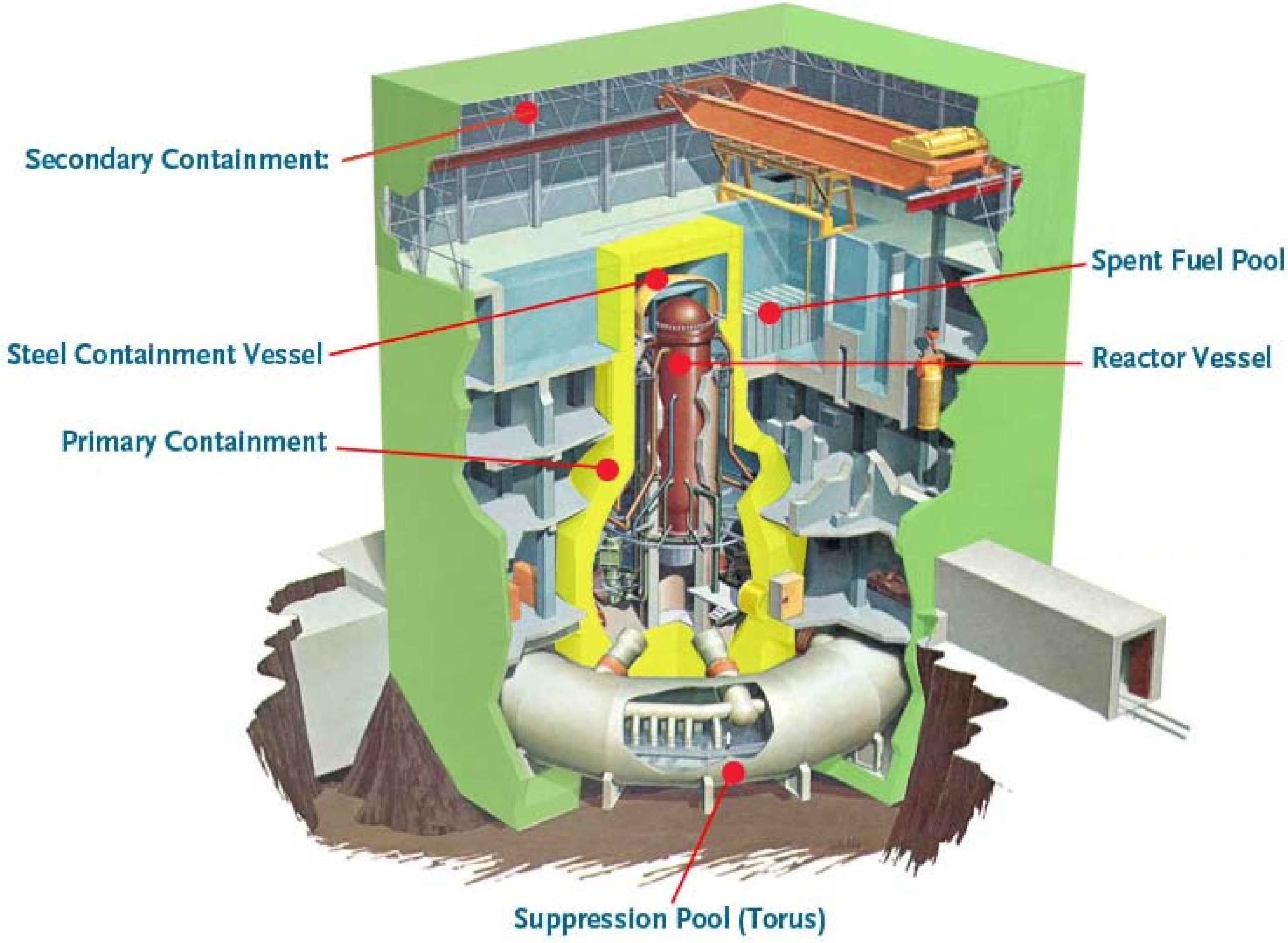
- All of the Fukushima units are BWR designs
- A BWR uses a single loop, whereas as a PWR uses two, isolated loops





All of Dominions units are PWR designs.

Fukushima Daiichi Unit 1

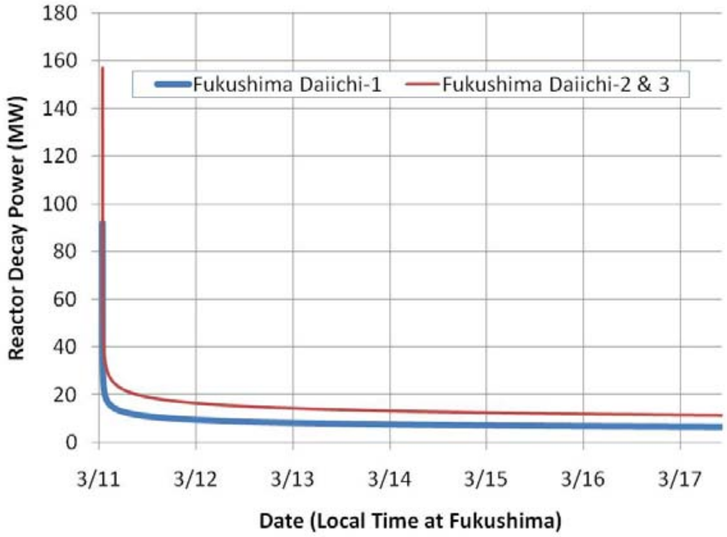


Event Initiation

- Magnitude 9 earthquake struck Japan's Sendi region on Friday, March 11, 2011
- The quake was 1,000 times stronger than any earthquake ever recorded where Dominion units operate.
- Despite the earthquake's incredible force, the Fukushima Emergency backup power sources operated as designed to cool the reactors
- The unprecedented quake created a significant tsunami greater than 46 feet above sea level
- The tsunami knocked out the backup power sources, resulting in the events that followed.

The Source of Heat at Fukushima Daiichi Units 1 & 2: Decay Heat

- Unit 1: 460 Mwe
- Units 2 & 3: 784 Mwe.
- When the reactors shutdown, the fission reactions essentially stop and the power drops drastically to <7% of full power in ~1 second.



- Decay heat is the heat released as a result of radioactive decay.
- The decay heat drops off very slowly after ~1 day where the decay power is < 2% of the normal operating power.
- After a year the decay power is ~0.2% of the operating power of the reactor.

Loss of Water to Cool the Reactor

About 300 station employees worked to restore power and cooling systems to the six reactors at the plant.

Hydrogen Generation

Zirconium-Water Reaction → Hydrogen

$$Zr \text{ (cladding)} + 2H_2O \rightarrow ZrO_2 + 2H_2$$

- About 98% of the fuel cladding material is zirconium
- Heat is generated by the reaction (exothermic), and the rate of the reaction increases with temperature
- Oxidation begins above ~1470 ° F, with rapid oxidation occurring at temperatures in excess of 2200 ° F.

Hydrogen Release

- Operators released steam and hydrogen through vents to ease pressure from the primary containment
- The units are designed to filter out radioactive material during primary containment venting
- The path for this filtered release is through duct work in the secondary containment to an elevated release point at the top of the reactor building

Hydrogen Detonation

A spark likely ignited a release of hydrogen from the secondary containment. Even so, the detonation did not damage the robust primary containment .

Hydrogen Detonation at Fukushima Daiichi Unit 1

Refuel Floor

Reactor Building

Status of the Fukushima Daiichi Nuclear Plant

- **External power is currently available to all units.**
- **Fresh water available for cooling.**
- **Unit 1** Initial hydrogen explosion, potential fuel damage
- **Unit 2** Fuel damage and potential damage to the primary containment
- **Unit 3** Hydrogen explosion, fuel damage
- **Unit 4** Fuel rods had been removed from the reactor vessel and placed in the used fuel pool. A fire and possible hydrogen explosion may have damaged the fuel pool
- **Units 5 and 6** Are Stable with power and cooling water circulation restored

Basic Facts About Radiation

- Annual natural background exposure is 370 millirem per year
- NRC regulatory limits annual exposure for nuclear workers to 5 rem (5,000 millirem) per year
- Dominion administrative sets annual exposure to 2.5 rem (2,5000) millirem per year
- Most nuclear station employees receive an insignificant radiation dose from work activities
- The risk of radiation exposure is minimized
  - ALARA Principle (As Low As Reasonable Achievable)

Potential Radiological Impact of the Fukushima Daiichi Units

- Radiation dose rates have fluctuated based on some of the relief operations, such as adding cooling water to the used fuel pools or removing water in the turbine building basement.
- Recent readings showed 12.4 millirem per hour at the main gate, 7.4 millirem per hour at the west gate and 78 millirem per hour on the side of the administration building facing the reactors.
- A person receives about:
  - 6 millirem per dental x-ray,
  - 2.5 millirem on a roundtrip cross country flight,
  - 1,110 millrem from the typical CT (CAT) scan of the head and chest.

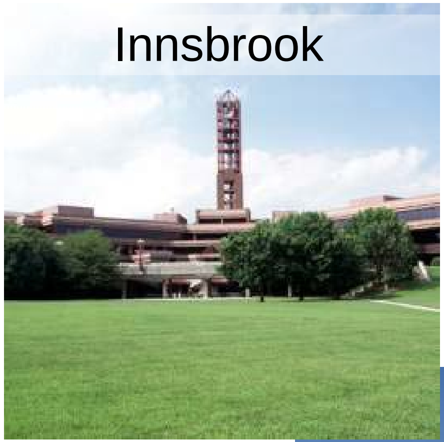
Potential Radiological Impact of the Fukushima Daiichi Units on the United States

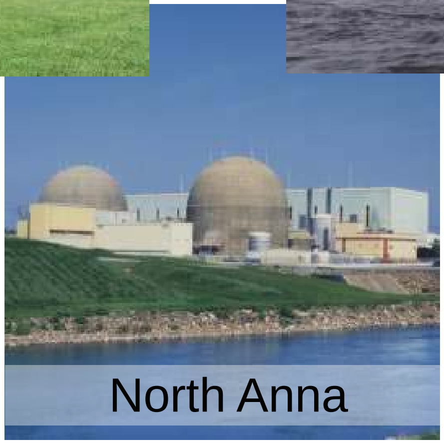
- Radiological impacts on the U.S. are expected to be insignificant:
  - The U.S. has an extensive network of radiation monitors around the country and no radiation levels of concern have been detected
  - Trace levels of radiation detected across the U.S.
    - The EPA states that levels detected are about one-millionth of the dose rate that a person normally receives from rocks, bricks, the sun and other natural background sources.
    - The annual dose to a person from this radiation level is equivalent to the amount absorbed from eating less than 4 percent of one banana – assuming you could slice it that small.

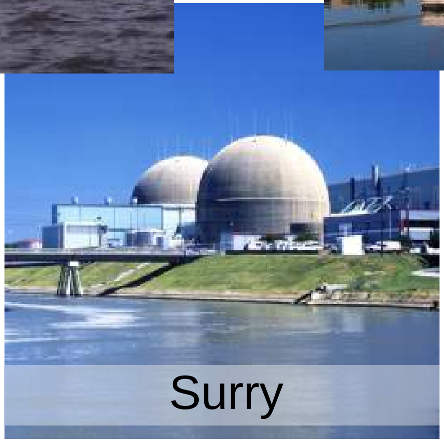
Information Sources

- Nuclear Energy Institute (www.nei.org)
- U.S. Nuclear Regulatory Commission (www.nrc.gov)
- U.S. Department of Energy (www.energy.gov)
- International Atomic Energy Agency (www.iaea.org)
- Health Physics Society (www.hps.org)
- Japanese Nuclear and Industrial Safety Agency (http://www.nisa.meti.go.jp/english/)
- Japan Atomic Industrial Forum (www.jaif.or.jp/english/)
- Tokyo Electric Power Company (http://www.tepco.co.jp/en/index-e.html)

Dominion’s Response to the Events in Japan

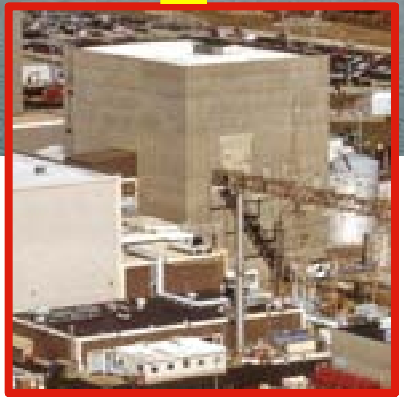






Dominion Response

Dominion has offered equipment, material and our knowledge from Millstone Unit 1 to the Japanese nuclear industry



Millstone Unit 1, which was shut down permanently in 1998, is similar to the damaged units at the Fukushima Daiichi power station in Japan

Dominion Response

- Our units are designed to withstand and safely operate or shutdown in a wide range of emergency situations, including earthquakes, flooding, extended loss of power and more
- Stations maintain high levels of readiness to respond to all events
- Worst-case accidents and acts of nature have been analyzed and procedures are in place to respond
- Operators spend 20 percent of their time in training to respond to potential events

Review and Validation Process Established

- Multidiscipline team established for:
  - ✓ Initiating reviews of our equipment, training & procedures based on lessons learned
  - ✓ Verifying the company's ability to mitigate:
    - Events that are considered to be beyond the design of the reactors
    - Total loss of offsite power
    - Internal and external flooding events
    - Other potential vulnerabilities

Defense in Depth

- The primary design and safety philosophy in engineering nuclear plants is called "defense in depth"
  - ✓ There are multiple, redundant safety systems to make sure plant personnel and the public are protected from any dangerous release of radiation
- Each unit is capable of responding to a station blackout:
  - A complete loss of all offsite power **AND** both emergency diesel generators fail to start or fail after starting

Responding to a Station Blackout: Defense in Depth

- Loss of all offsite power to the station
- Station units automatically shutdown
  - Equipment for normal operation loses power
  - Control rods automatically drop into core to shutdown reactor
  - Emergency Diesel Generators (EDGs) automatically start to provide power to safety equipment
  - Each unit is designed to be safely maintained in this condition or to be safely cooled down
- Safety equipment maintains the reactor in a safe condition
  - Independent & redundant (diesel generators, pumps, valves, and other equipment)
  - Only one of each piece of equipment needed, but two are provided by design
  - An additional diesel generator, referred to as the Station Blackout (SBO) Diesel is available as a backup power supply to necessary equipment, in the event of an EDG failure

Responding to a Station Blackout:
Defense in Depth

- Batteries supply backup power for instrumentation and control functions during Blackout conditions.
- Should battery power be lost, procedures and equipment are also available to maintain coolant inventory and core heat removal until power can be restored (with or without the EDGs)
- Operators are regularly trained on these and similar procedures.
  - Initial Licensed Operator Training is approximately 18 months in duration
  - Licensed Operator Continuing Training is one week out of every rotating shift cycle

Responding to a Station Blackout: Defense in Depth

Priorities during Blackout Conditions:

- Coolant Inventory
  - ✓ Maintaining adequate water inventory for the reactor core to make-up for normal leakage paths
- Core Heat removal
  - ✓ A source of cooling to remove residual heat (heat produced from the radioactive decay of fission products after the Reactor is shutdown).
- Power restoration
  - ✓ Power to at least one set of safety equipment to terminate the event

Responding to a Station Blackout:
Defense in Depth

Methods to deliver water (coolant inventory & core heat removal):

- **Passive Accumulators**
  - ✓ Pressurized to allow automatic injection of their water into the reactor core (no electrical power required)
- **Turbine-Driven Auxiliary Feed Water (AFW) Pump**
  - ✓ Steam from steam generators (SGs) is used to spin a turbine which drives the pump to deliver water to the SGs for removal of residual heat (no electrical power required).
  - ✓ Associated water sources for this function are:
    - Auxiliary Feed Water Supply Tank
    - Fire Protection Water System (backup)
    - Service Water (backup)
    - Replenishment capability from Lake/Sound/River, as applicable to the site

Spent Fuel Pool Cooling:
Defense in Depth

- All Dominion units use multiple pumps and heat exchangers to provide cooling for the water in the spent fuel pool.
- During a loss of off-site power, the design allows for power to not be restored to these pumps for several hours in order to allow for more immediate station needs to be met.
- Multiple backup sources of water are available to replenish water in the spent fuel pools, such as:
  - The Refueling Water Storage Tank
  - Primary Grade Water
  - Condensate Tanks
  - Service Water
  - Fire Protection System

Key Points to Remember

- The strength of the Japanese earthquake was at least 1,000 times more powerful than any earthquake ever recorded near any of our nuclear facilities
- Dominion’s nuclear power stations are built to withstand any seismic event conceivable for their locations
- Our stations are designed and maintained to protect critical safety systems against flooding and we have multiple redundant systems to provide backup electricity.
- Dominion has a robust emergency plan designed to protect the public. This plan is exercised routinely with the state and local emergency management agencies

In Closing

- Protection of the health and safety of the public is at the forefront of Dominion's nuclear operations
- The company demonstrates the highest levels of safety and reliability in operating its nuclear stations
- Dominion and its industry peers will continue to share information and will work to learn from the events in Japan
- Dominion, the industry and federal regulators will assess lessons learned and incorporate additional actions that can be taken to enhance our readiness to respond to severe accidents

Dominion®