Potential Climate Impacts and Adaptation Options for Electricity and Natural Gas Systems in the San Diego Region

January 24, 2019

Presentation Outline

- Project Motivation & Goals
- Methodology
- Findings
- Key Takeaways

Project Motivation & Goals

Dr. Robert Kay
Chris Arends – Meteorology Program Manager, SDG&E
Deanna Haines – Director, Policy & Environmental Strategy, SoCalGas & SDG&E

Project Motivation

- Energy utilities provide **critical services** to California communities
- **Climate change threatens** energy utilities' ability to deliver safe, reliable, and affordable power and gas
- Prior to the study, there was **limited understanding** of how climate change might impact energy utilities and how utilities might undertake adaptation

Project Goals

- Develop an in-depth understanding of **energy sector climate change vulnerabilities** using best available climate science
  - Electricity: Coastal hazards
  - Gas: Coastal & inland hazards
- Identify an **approach for undertaking adaptation** and specific **adaptation measures** for utility assets, systems, and operations
- Develop findings at a level of detail appropriate to **inform utility policy and planning**

The Utility Perspective

- Learn about the **latest climate science** and how it applies to our system
- Identify system **vulnerabilities**
- Integrate **best practice** adaptation & resiliency methods/options into planning

Methodology

Dr. Judsen Bruzgul

Methodology

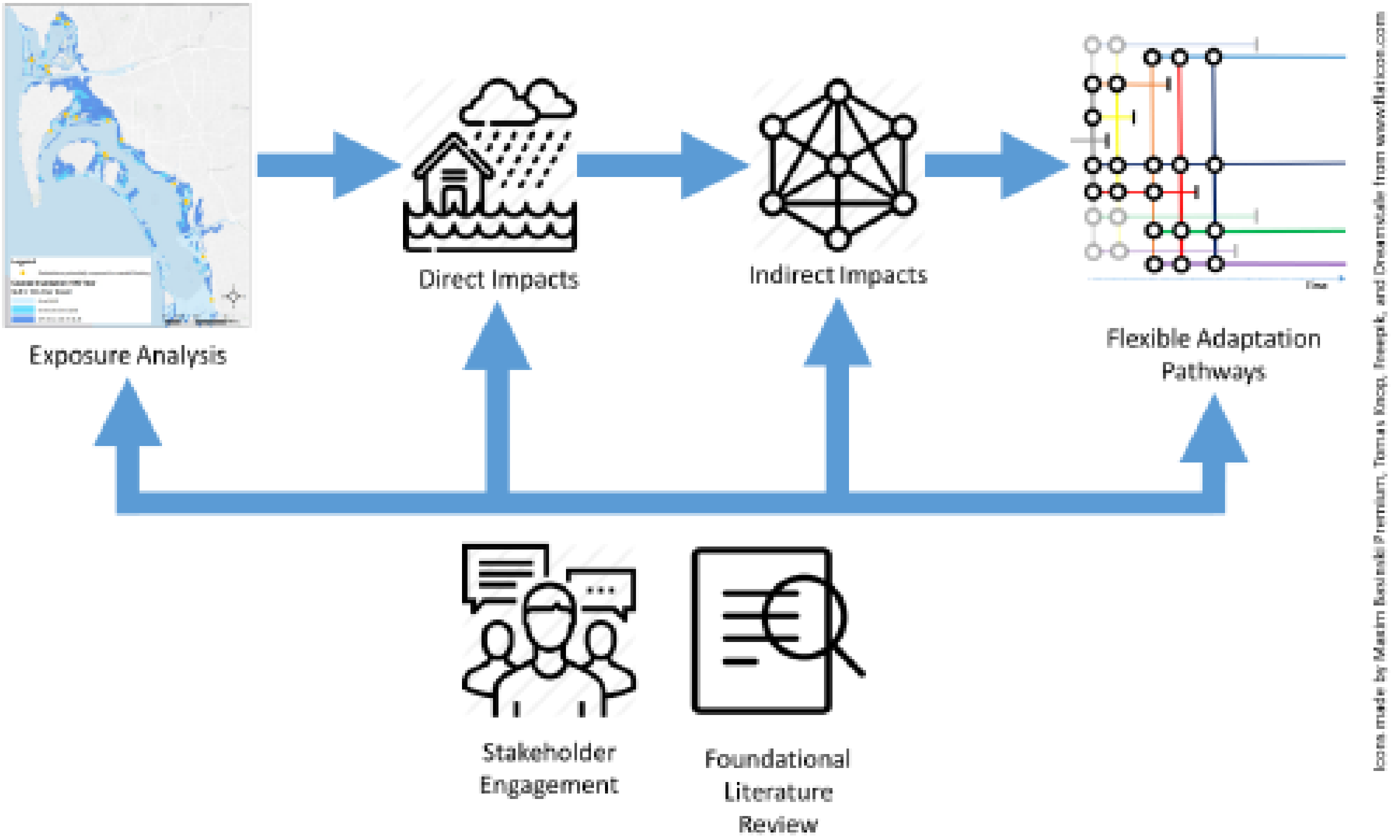


Figure 2: Visual Representation of Study Methodology

Engaging Partners

- Working side-by-side with utilities enabled the project to **draw on utility knowledge** rather than assumptions based on desk research, resulting in:
  - A more **accurate characterization** of potential impacts
  - A more **nuanced understanding** of the broader implications of potential impacts
  - A better sense of the **viability of adaptation options**
  - More meaningful, useful analysis that is tailored to **informing utility adaptation action**
  - A sense of **ownership** of results and utility adaptation actions

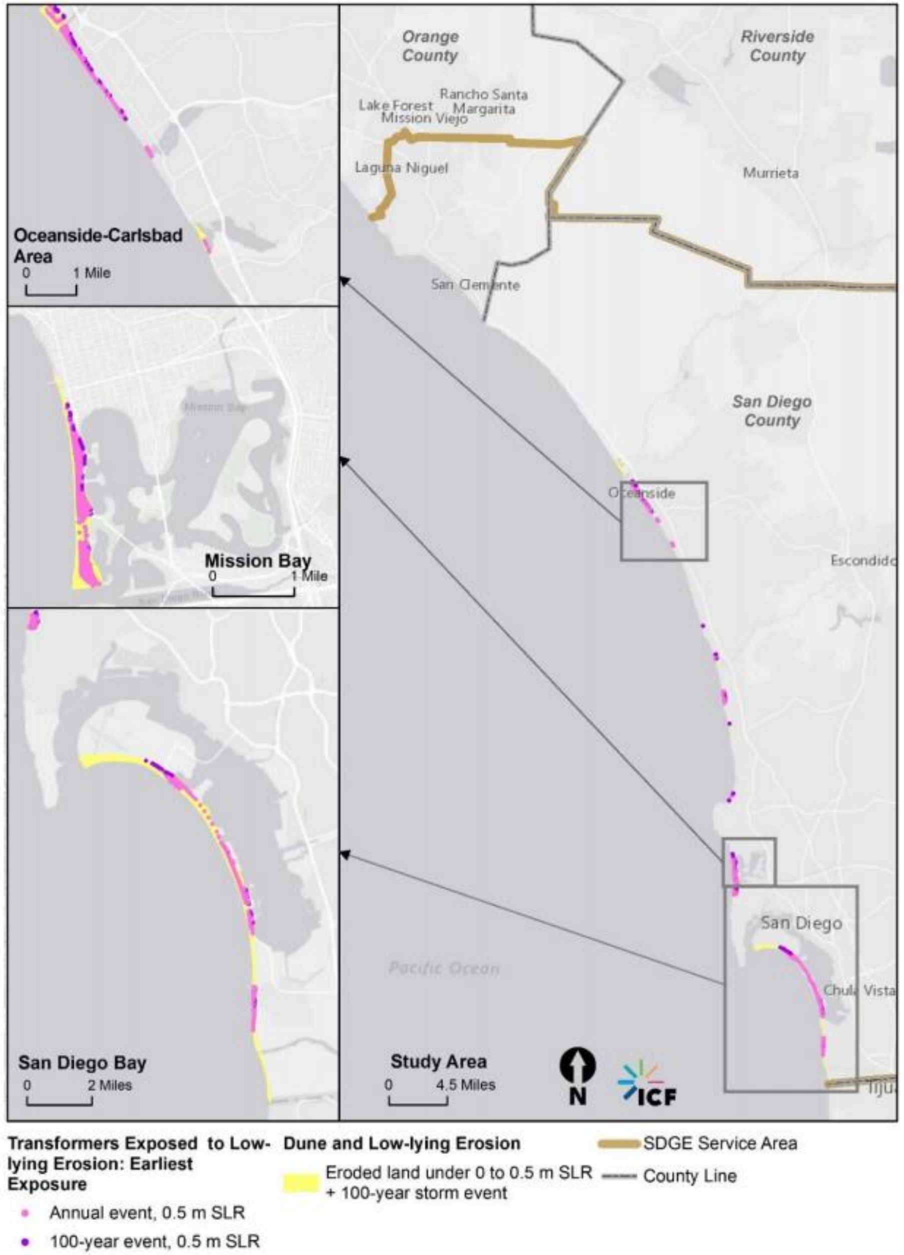
Climate Hazard Exposure

- Time Horizons: 2050 and 2100

Hazard	Data Source	Electricity	Gas
Coastal Hazards • Tidal inundation (annual storm) + SLR • Coastal wave flooding (100-year storm) + SLR • Coastal erosion + SLR	CoSMoS & SPAWAR	x	x
Wildfire	Cal-Adapt (Westerling 2018)		x
Extreme Heat	Cal-Adapt (Pierce et al., 2014)		x
Inland Flooding	FEMA Flood Zones		x
Geologic Instability	CA Geologic Survey		x

Detailed Coastal Modeling & Analysis

- Analyzed exposure of assets to coastal wave flooding, tidal inundation, and coastal erosion
  - Novel erosion model, combined multiple dune and low-lying inlet erosion products, including USGS CoSMoS 3.0 COAST and SPAWAR as well as a geomorphic interpretation of future exposure
- Analyzed depth of flooding at 13 key substations



Potential transformer exposure to low-lying erosion by mid-century

Direct Impacts Specific to SDG&E

- Literature review
- Workshops and interviews with SDG&E and SoCalGas

Electricity: VOLL & Interdependencies Analysis

1. Analyze exposure
2. Define asset loss scenarios (focus on substations)
3. Analyze information on distribution system design to determine customers impacted under each scenario
4. Utilize Value of Lost Load and Expected Unserved Energy to determine economic impacts to customers
5. Assess key interdependencies and impacts from loss of power through review of local contingency planning

Electricity: Asset Loss Scenarios

Scenario 1 **Future Periodic Coastal Flooding**	• Simultaneous 12-hour loss due to flooding at 12 substations
Scenario 2 **Future Storm Coastal Flooding**	• Simultaneous full loss for two weeks due to flooding at four substations
Scenario 3 **Extreme Future Storm Coastal Flooding**	• Simultaneous loss for two weeks at 13 substations

Natural Gas: Gas Market Modeling

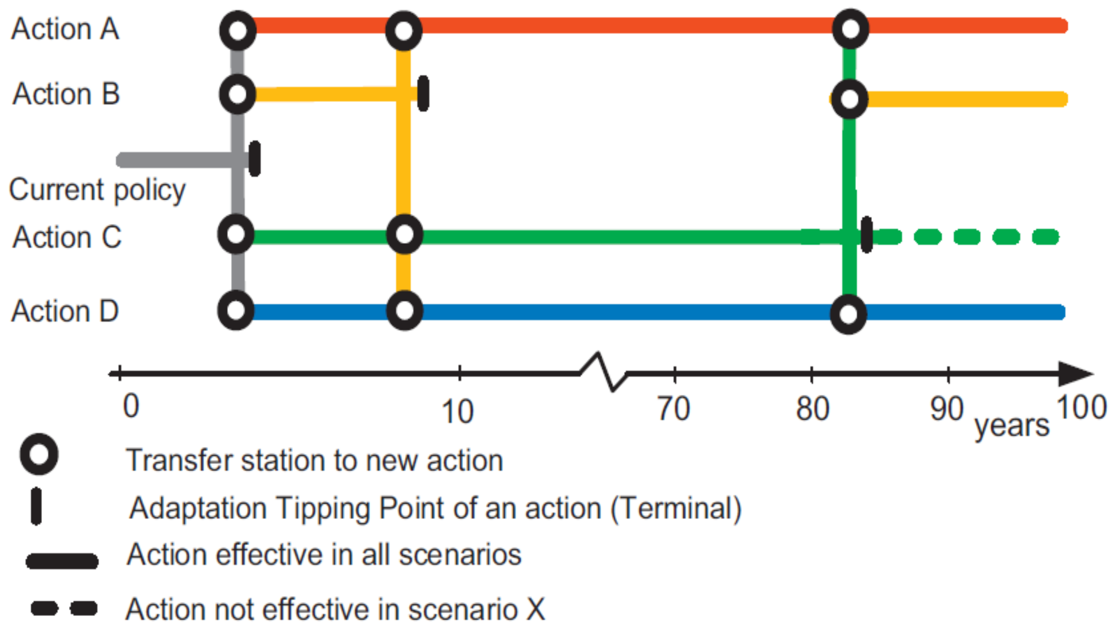
- Objective:
  - Assess impacts of climate-driven changes in the gas market on SDG&E service territory
- Approach:
  - Define one baseline and one climate-driven scenario
  - Use ICF Gas Market Model to model reductions in supply due to:
    - climate-driven demand increases outside of SDG&E service area, and
    - climate-driven increases in peak demand inside SDG&E service territory driven by increases in Cooling-Degree Days (CDD).

Adaptation Methodology

- Background Research
  - Brief literature review on energy sector adaptation strategies
- Workshops
  - **Workshop 1:** Multi-criteria approach for evaluating adaptation measures
  - **Workshop 2:** Utility expert elicitation on adaptation

Flexible Adaptation Pathways

- What are they?
  - A set of adaptation measures that are **implemented over time** to allow for **adjustment based on new information and circumstances**
- What is the benefit?
  - A flexible adaptation pathways approach helps **manage future deep uncertainty** by allowing decision-making to **adjust based on new information or conditions** (e.g., new technologies, customer needs, climate conditions, and economic and policy landscape)



Source: Haasnoot et al. 2013

Findings: Electricity

Beth Rodehorst

Electricity Asset Exposure

- **Thousands of assets** potentially exposed by mid- and end-of century, under annual and 100-year storm events
- **Mostly distribution**, not transmission

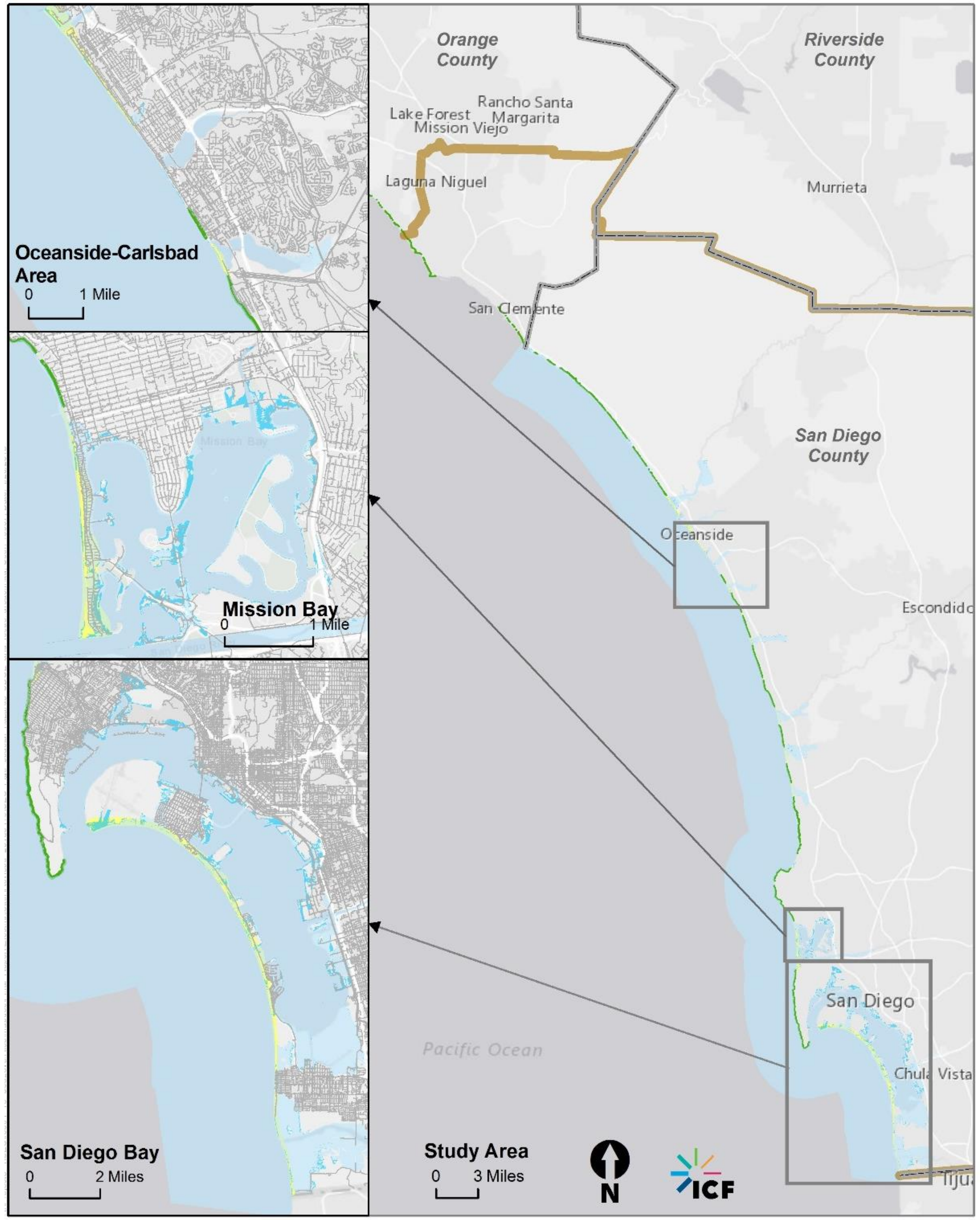
Legend

Coastal Wave Flooding from 100-year Event
- 0 m SLR
- 0 m to 0.5 m SLR

Dune and Low-lying Erosion
- Eroded land under 0 to 0.5 m SLR + 100-year storm event

Cliff Erosion
- Eroded land under 0 to 0.5 m SLR

- SDG&E Electric Line Assets
- SDGE Service Area Boundary
- County Line

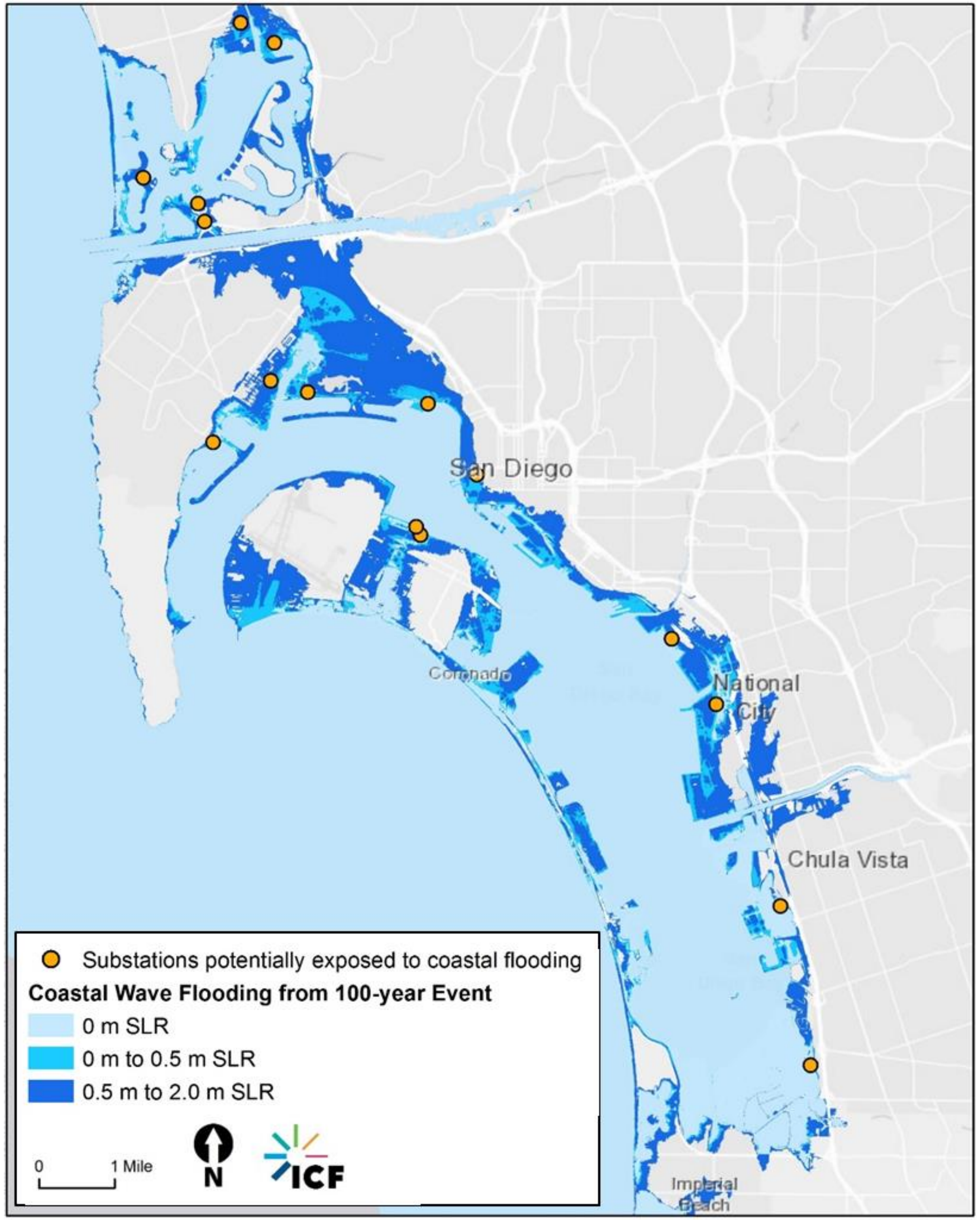


Potential Direct Impacts to Poles, Lines, & Duct Banks

- Transmission
  - Limited potential exposure to transmission assets
  - Potentially exposed assets concentrated around Mission Bay and San Diego Bay
  - Asset types: Duct banks and overhead structures
  - Duct banks sensitive to saltwater corrosion, overhead structures have limited sensitivity
- Distribution
  - More exposure to distribution network.
  - Poles, anchors, and guy wires vulnerable to scour and corrosion, as well as debris and wave forces from temporary inundation. Theoretically could topple if damage is not addressed.

Exposure: Substations

- Substations are among the most critical of SDG&E’s potentially exposed assets
- Potential exposure under 100-year flooding
  - Present day
    - 2 substations
  - Mid-century (0.5 m SLR)
    - +2 (4 total) substations
  - End-of-century (2.0 m SLR)
    - +12 (16 total) substations



Potential Direct Impacts to Substations & Transformers

- Debris in water can damage infrastructure
- Inundation from water can damage electrical equipment
- Saltwater is corrosive, meaning temporary inundation can increase maintenance/repair needs even after water has receded

Indirect Impacts

- Economic Losses to Customers
  - Potential economic loss to customers from costs of unserved energy range significantly across the impact scenarios
  - Cost of Unserved Energy ($) = VOLL ($/kWh) x Unserved Energy (MWh) x 1000

	Cost of Unserved Energy Estimates ($Millions)		
Impact Scenario	**Low**	**Medium**	**High**
1: Future Periodic Coastal Flooding	$0.3		$0.3
2: Future Storm Coastal Flooding	$5.4	$57.3	$113.5
3: Extreme Future Storm Coastal Flooding	$1,180.8	$12,622.0	$25,021.7

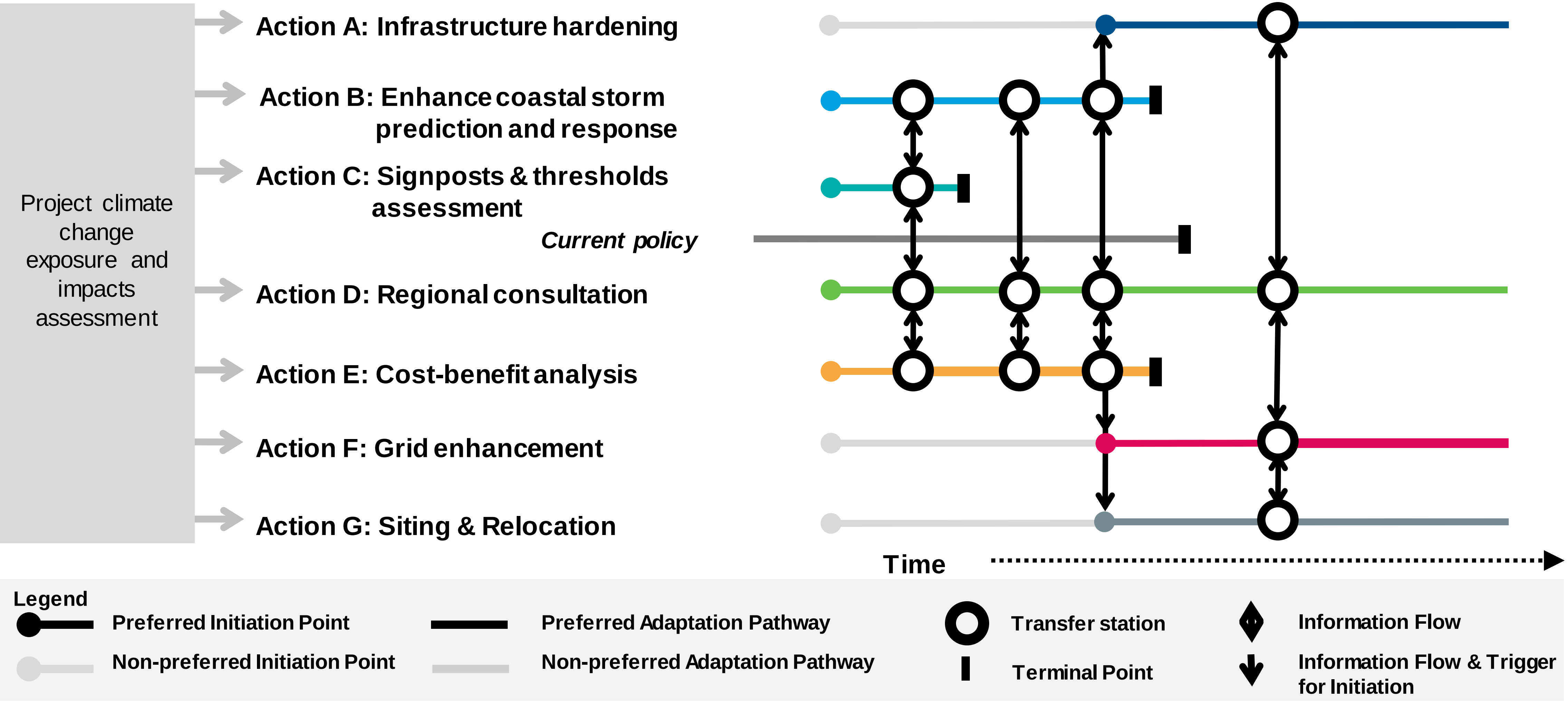
Indirect Impacts

- Potential Impacts to Interdependent Critical Systems and Customers Under Impact Scenario 3
  - Of the >12,900 customers impacted, 517 are critical
  - Disruptions to operations of several sewage pumping stations, a hospital, ports (airport and sea port), and a naval yard
    - Sewage pumping stations: Among the most significant concerns. Could result in release of biohazard material, creating public health concern.
    - Hospital: Patients who are less mobile, rely on equipment to survive, and require more intense care could suffer. Impacts could be exacerbated by obstructed roadways.
    - Airport: Loss of commercial use of airport would create significant disruptions.
    - Port: Disruptions could impact hundreds of tenant businesses and over 20 public parks, causing economic losses from tourism and commercial operations
    - Naval Yard: Undetermined

Adaptation Workshop Outcomes

- **Workshop outcomes:**
  - Utilities were able to quickly and easily identify adaptation options
  - Utilities expressed a need to:
    1) **integrate additional climate stressor monitoring** into existing weather monitoring activities
    2) **integrate adaptation into existing decision-making processes** to support adaptation implementation and cost recovery

Flexible Adaptation Pathways

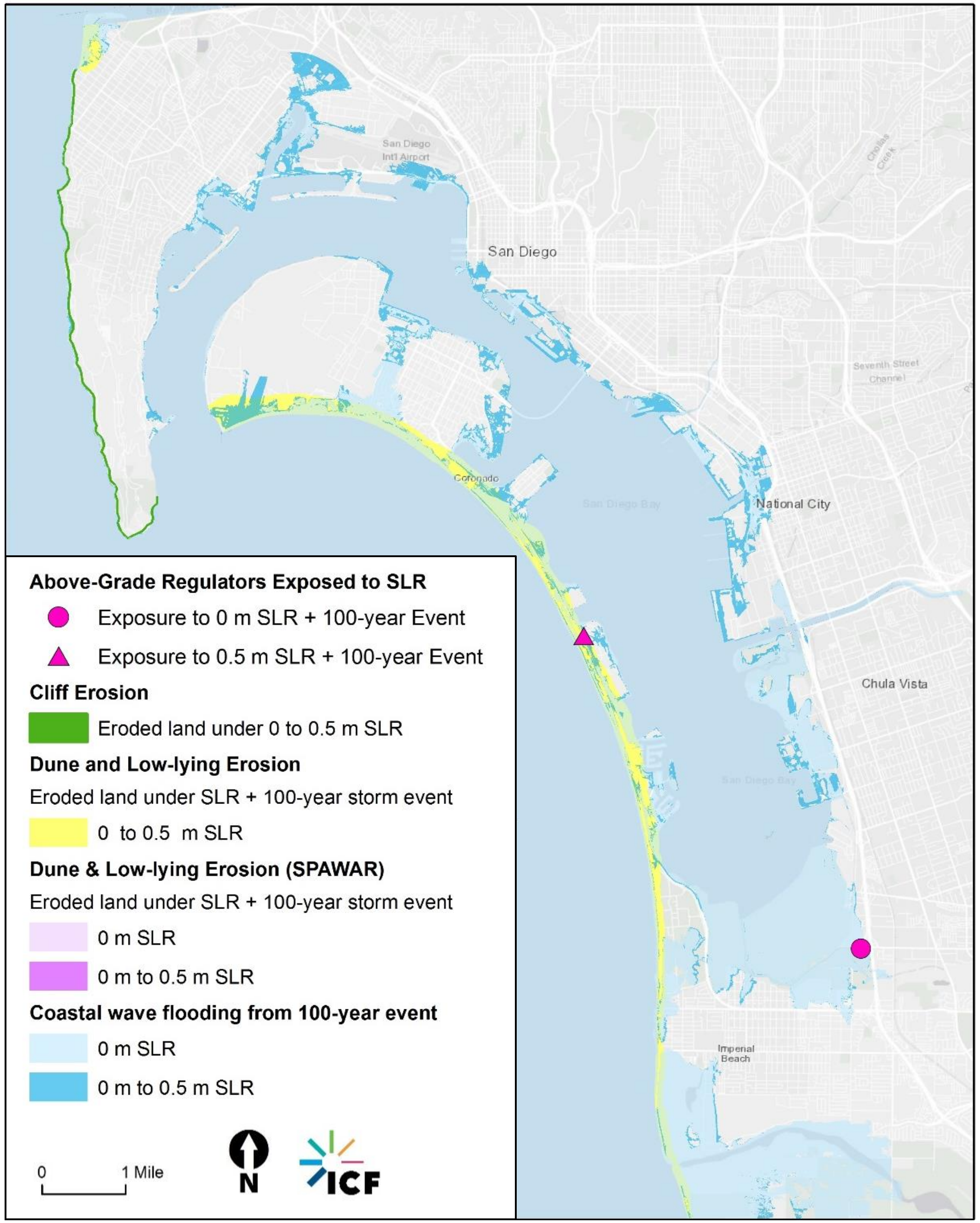


Findings: Gas

Beth Rodehorst

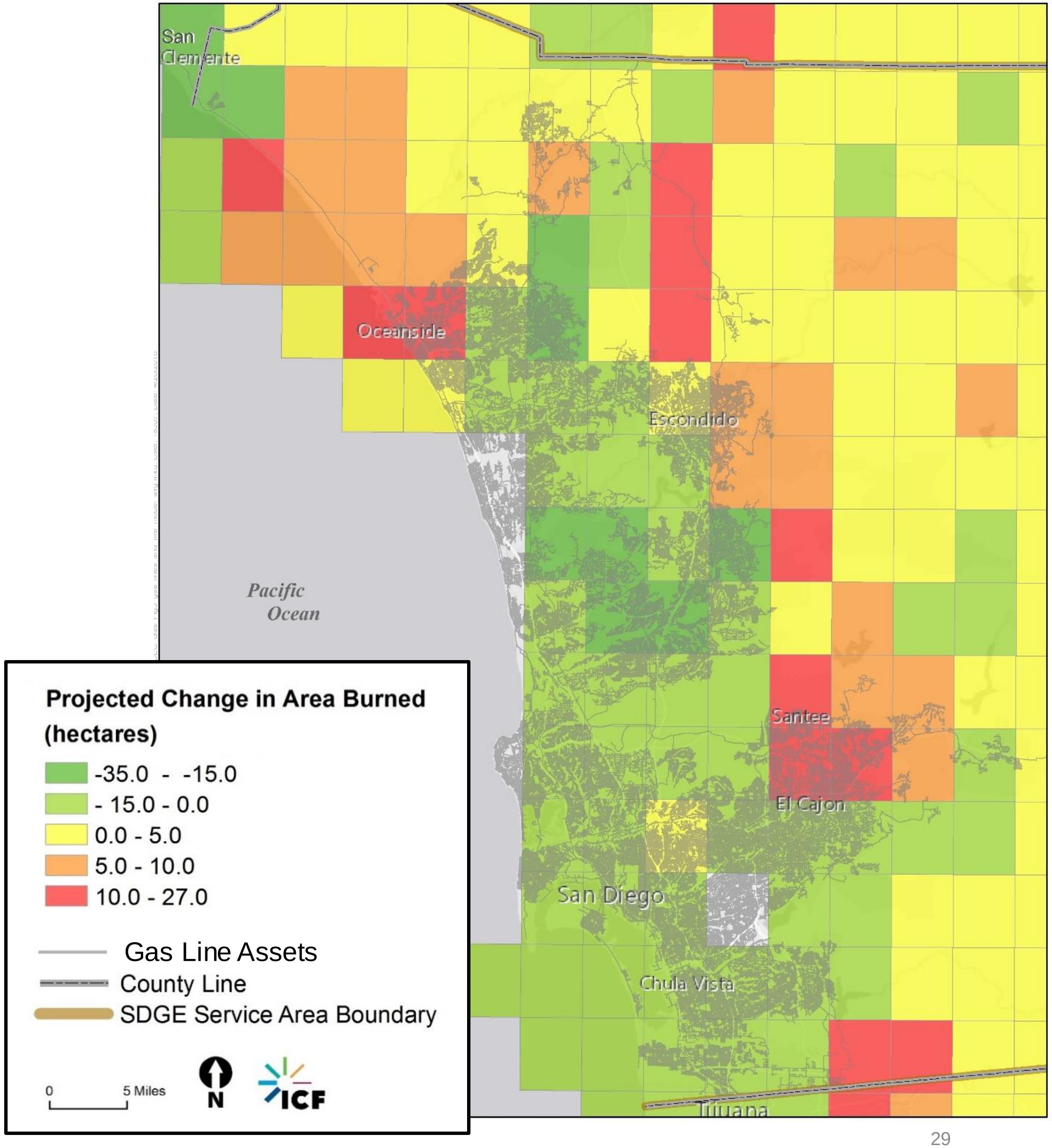
Exposure: Coastal Hazards

- <1% total gas system assets potentially exposed
- Impacts expected to be limited due to limited system sensitivity, as pipelines are buried and pressurized
- Assets at water crossings are among the most sensitive
- Assets exposed to erosion could experience physical damage, disrupting service



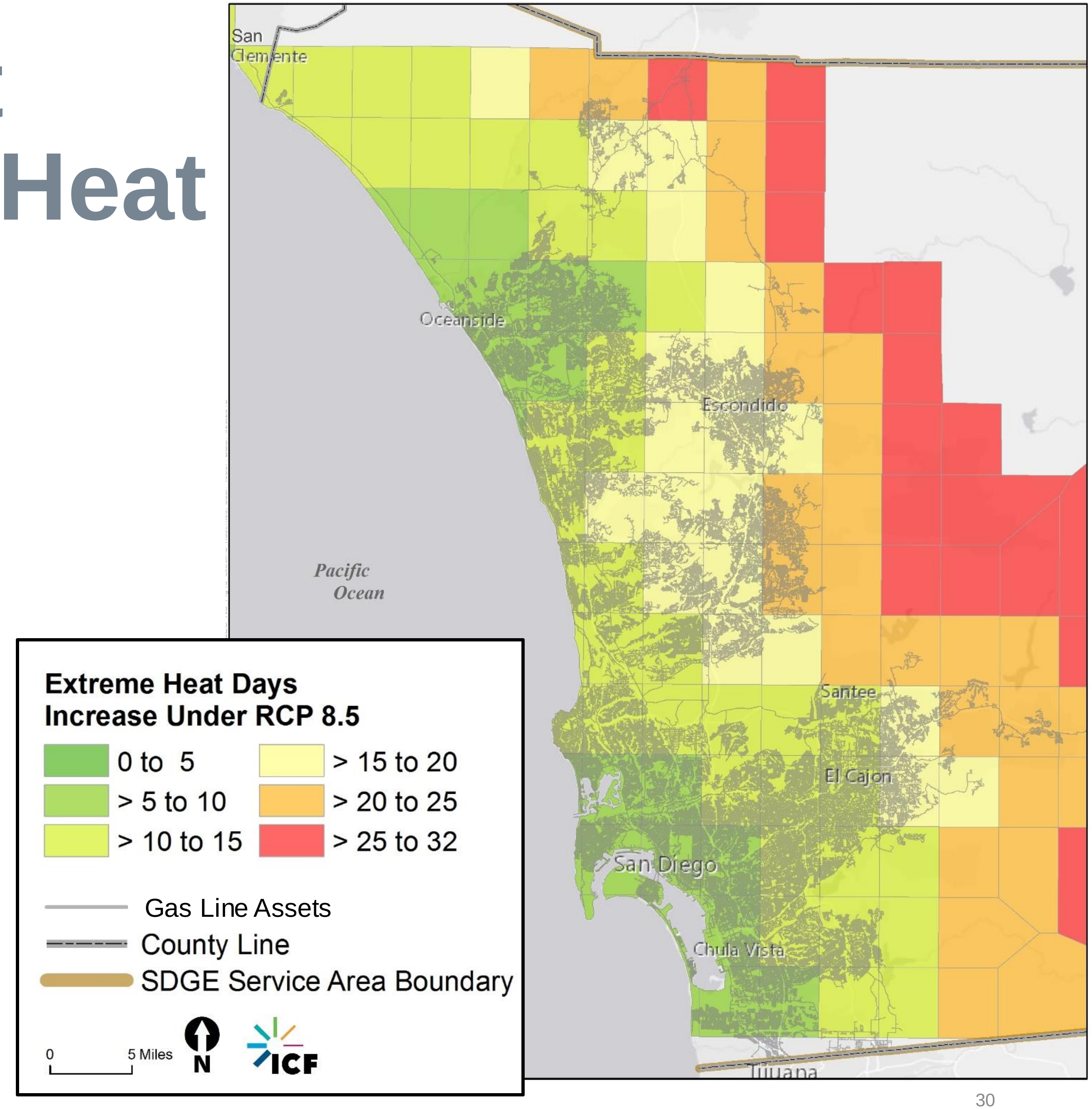
Exposure & Direct Impacts: Wildfire

- Overall, 19% of point assets and 21% of line assets expected to experience increase in wildfire area burned
- Exposure is concentrated in specific areas
  - 38 above ground regulators located in areas projected to experience increase in wildfire, the majority of which (37/38) are in the northern parts of the service territory
- Most assets are underground and not sensitive to wildfire
  - Greatest risk: damage to aboveground regulators could disrupt service
  - When homes/buildings are damaged, meters are damaged too
  - Real cost to gas system is in cutting off and later restoring service to customers



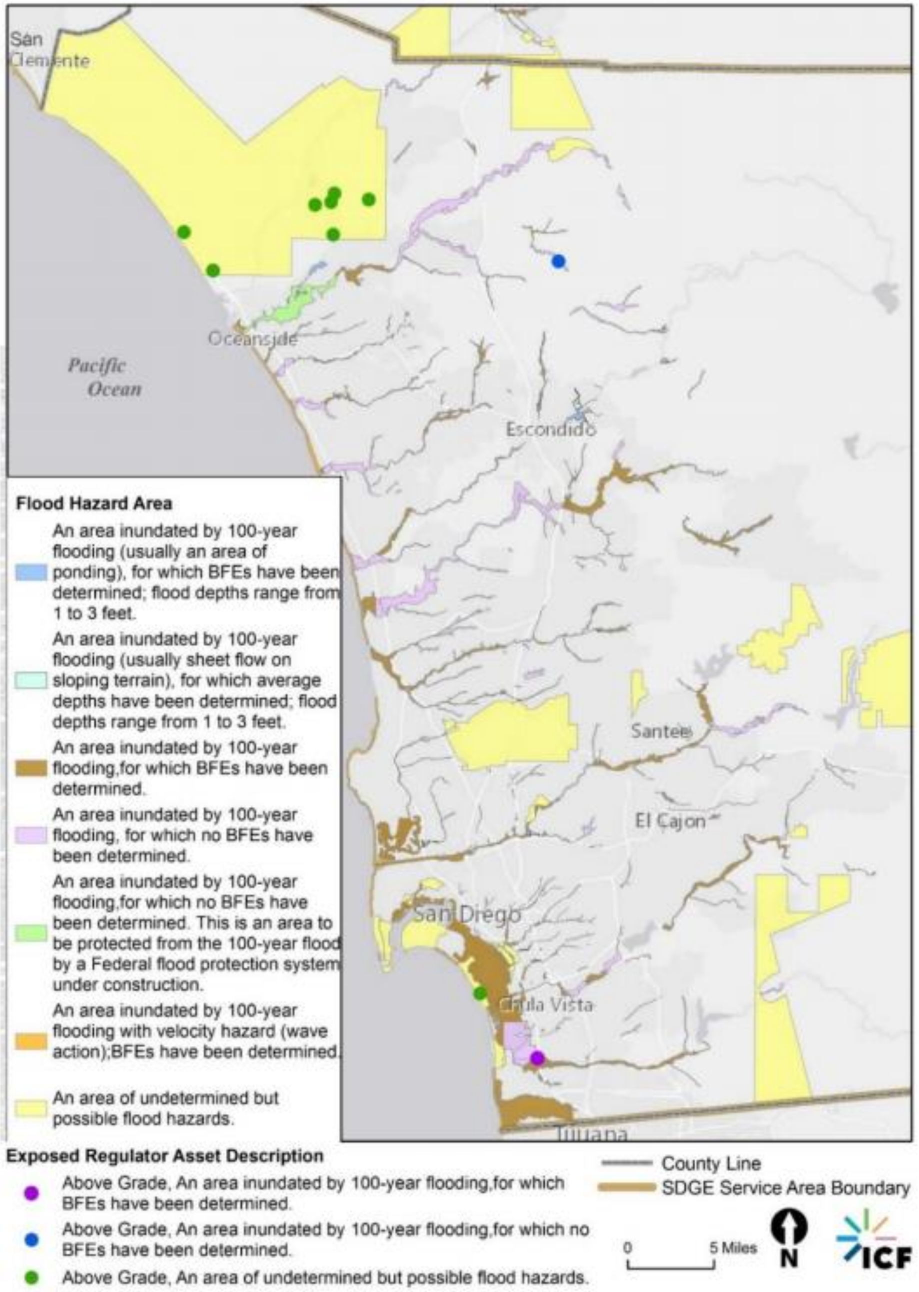
Exposure & Direct Impacts: Extreme Heat

- Majority of assets (88%) projected to experience an increase in extreme heat days, up to 14 additional days annually
- Infrastructure itself is not very sensitive to heat
- Impacts more likely to arise from operations:
  - OSHA rules/worker safety issues
  - More space cooling requirements in compressor stations
  - Lower density of gas = more volume needed to meet demand



Exposure & Direct Impacts: Inland Flooding

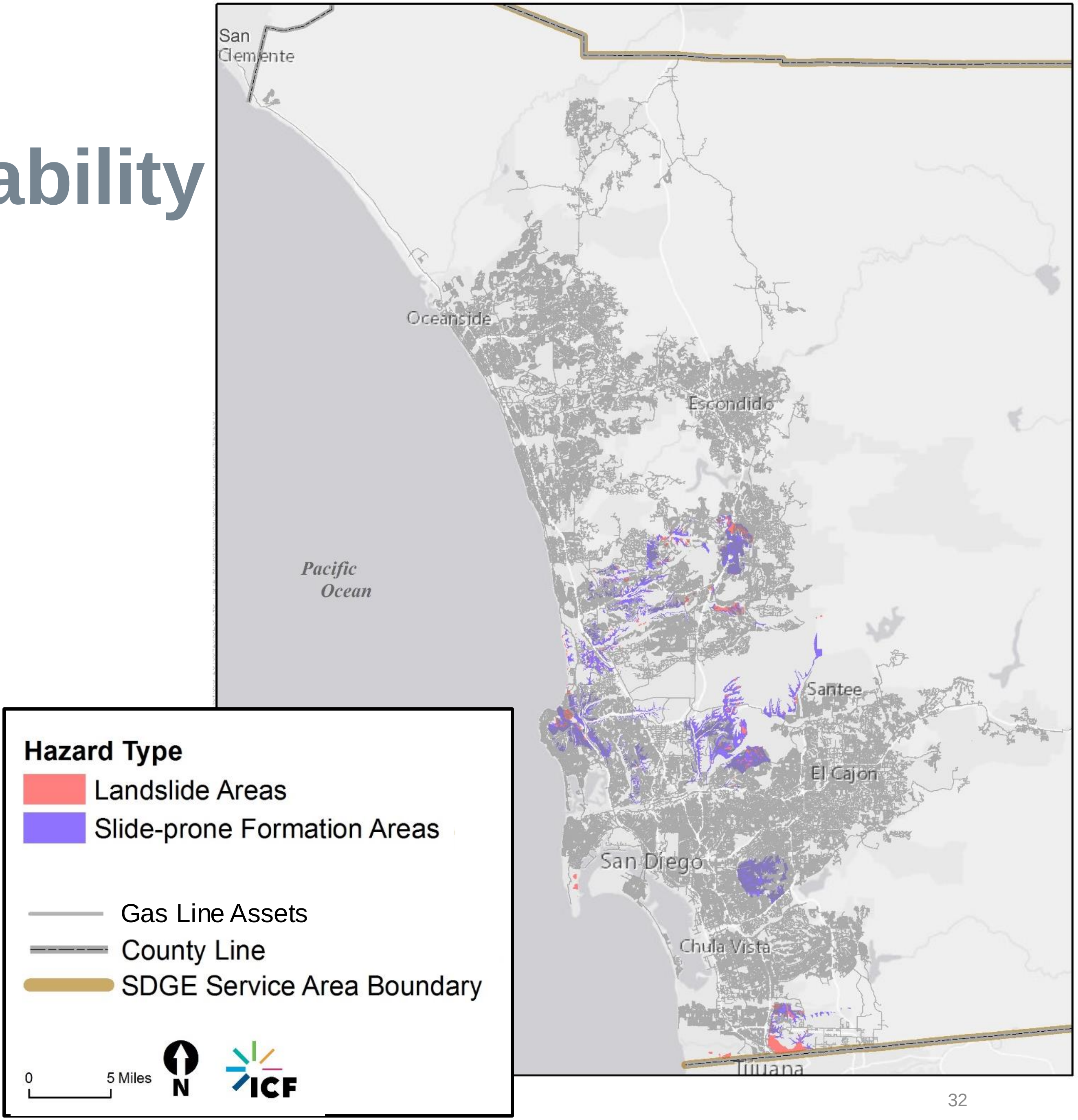
- Across the *entire* service territory, only about 2% of linear feet of gas lines are in the 100-yr flood zone, and an additional 3% are in the 500-yr flood zone
  - Less than 1% of gas point assets are in the flood zones.
- However, that exposure is clearly concentrated in flood-prone areas - some areas may have all, or almost all, of their assets exposed.
  - If assets are critical in these areas, impact could be larger than this 1% proportion suggests
- Impacts are expected to be limited since system is largely underground, and aboveground assets have limited sensitivity to floods
- Assets most likely to experience damage are those at water crossings and aboveground regulators



ICF

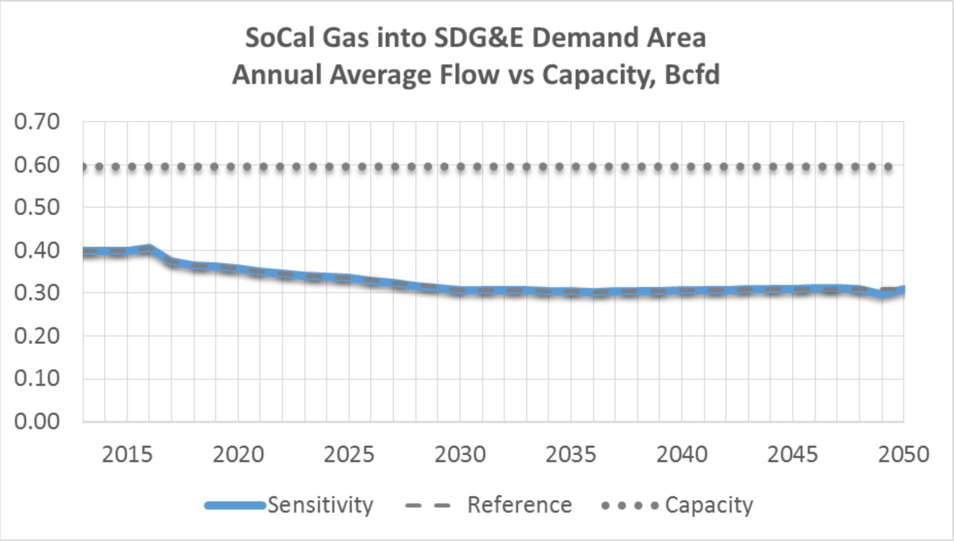
Exposure & Direct Impacts: Geologic Instability

- About 2% of linear feet of gas lines, and 4% of gas point assets, are in landslide-prone areas.
  - Particular issue in area north of San Diego
- Underground pipelines *are* sensitive
  - Loss of ground support = risk of rupture
- Ground service connections could be damaged or severed due to landslides
- Settlement can cause gas meters and other infrastructure to lean
- Secondary impacts
  - If pipeline runs along roadway that is damaged by landslide, sinkhole, etc., service may need to be shut down so that road can be repaired

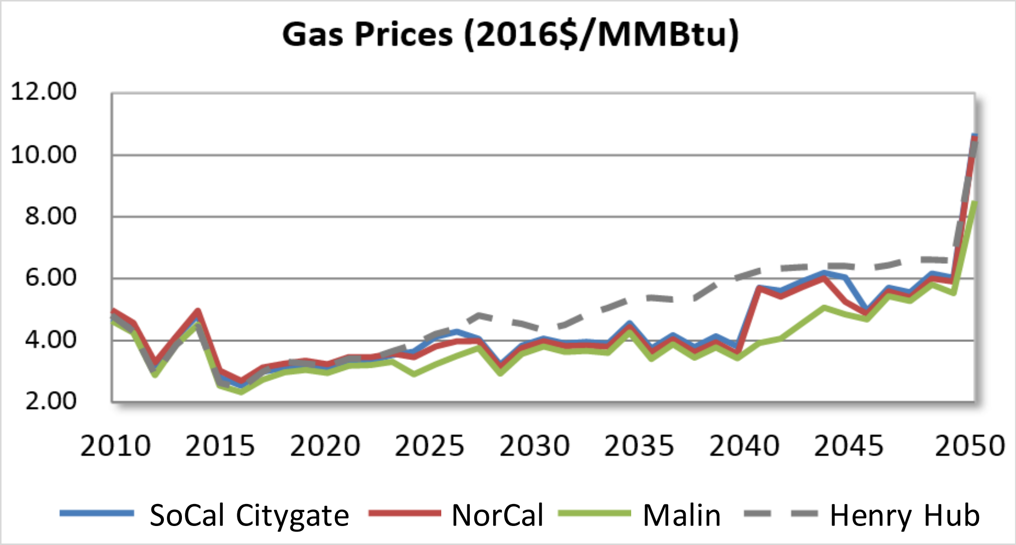


Indirect Impacts: Gas Market Model Climate Hazard Case

- Decline in gas demand similar to reference case
  - Increases in power generation gas demand due to increased CDD are offset by decreases in gas use in other sectors due to higher prices and reduced space heating needs



- Greater variability in prices
  - Due to changes in gas demand from increased CDD and changes in hydropower variability
- Price increase of $1.25 above reference case at Henry Hub (grey)
- Climate extreme shock drives prices above $10/MMBtu



Flexible Adaptation Pathways

Project climate change exposure and impacts assessment

Action A: Upgrade infrastructure design and maintenance specifications

Action B: Integrate climate change hazard maps into planning & operations

Action C: Signposts & thresholds assessment

Current policy

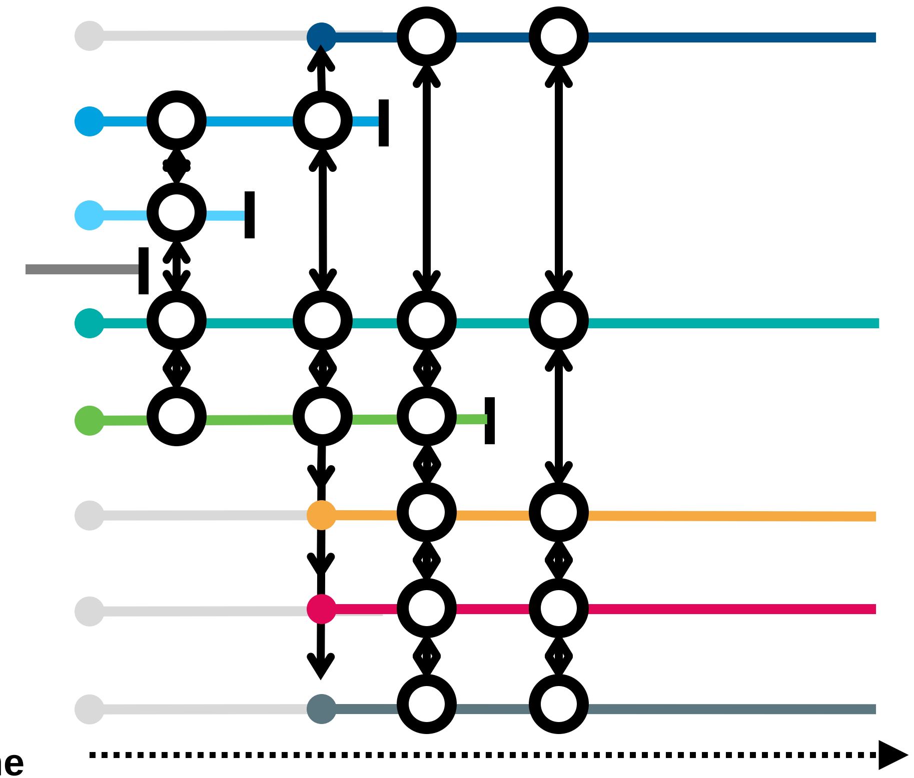
Action D: Regional consultation

Action E: Cost-benefit analysis

Action F: Enhance system management technology

Action G: Siting & Relocation

Action H: Adjust gas supply and storage system to enhance resiliency



Time

Legend

- **Preferred Initiation Point**
- **Non-preferred Initiation Point**
- **Preferred Adaptation Pathway**
- **Non-preferred Adaptation Pathway**
- **Transfer station**
- **Terminal Point**
- **Information Flow**
- **Information Flow & Trigger for Initiation**

Key Takeaways

Dr. Robert Kay
Chris Arends – Meteorology Program Manager, SDG&E
Deanna Haines – Director, Policy & Environmental Strategy, SoCalGas & SDG&E

Key Takeaways: Electricity

- Exposure
  - Significant number of assets projected to be exposed to coastal hazards
  - Areas of concern
    - Low-lying areas around bays and estuaries (e.g., Mission Bay & San Diego Bay)
    - Coastline adjacent to erodible cliffs and dunes
- Direct Impacts
  - Most significant: Damage to substations near Mission Bay & San Diego Bay, potentially leading to service disruptions to thousands of customers
  - Increased maintenance or repair costs
- Indirect Impacts
  - Potential costs to customers: >$25 billion under an end-of-century extreme SLR scenario
  - Communities around vulnerable substations could experience adverse consequences from loss of electric service to sewage pump stations, a hospital, San Diego International Airport, the Port of San Diego, and the Navy Yard
- Adaptation is needed

Key Takeaways: Gas

- Direct impacts
  - Gas assets and services likely to experience limited impacts and widespread disruptions are not expected due to limited projected exposure to climate hazards, and existing physical protections that limit potential impacts.
  - Impacts may occur in the form of increased repair/maintenance needs or localized disruptions.
- Impacts to gas market
  - SoCalGas has the capacity to adapt to projected changes
  - The climate "shock" 2050 scenario would not lead to shortfalls in regional supply, as there is sufficient pipeline capacity
  - Limitation & area for future research: Daily peak gas demand
- Adaptation is still needed
  - Impacts overall may be limited, but system will experience impacts to some extent that will require adaptation

Future Research Needs & Recommendations

- How to best encourage implementation of adaptation measures
  - E.g., Regulatory barriers to adaptation, whether new regulations could facilitate adaptation
- How technology can be deployed in the electricity and natural gas supply and distribution systems to optimize resiliency
  - E.g., smart grid technologies (electricity), smart meters and other remote monitoring systems (natural gas)
- Evaluate the benefit of distributed storage to reduce sensitivity of natural gas supply
- Changes in customer vulnerability and resilience over time, including socio-economic scenarios and changes in electricity assets
- Potential indirect impacts

Using the Results: Electricity

- SDG&E has partnered with Scripps Institute of Oceanography, the Port of San Diego, and San Diego Airport Authority to deploy sensors to measure high water levels to reduce risk and assure uninterrupted service to SDG&E customers in the area during flooding events.
  - Wave-current sensors will be placed in areas identified as highly vulnerable to sea-level rise and that has experienced past flooding events. Observations will be collected to determine how waves currently contribute to high water levels at this location.
  - The wave measurements will be used to develop and validate a wave model specific to San Diego Bay.
  - A web-based visualization tool will monitor and predict waves and water levels going forward.

Using the Results: Natural Gas

- Key Takeaway: Gas system is very resilient due to its underground nature
  - Diversity in energy supply is critical to adaptation & resilience
- Augmented CEC research with Four Case Studies of real events from 2017
  - (1) Hurricane Harvey in Texas, (2) Hurricane Irma in Florida, (3) Wildfires in NorCal, and (4) Wildfires in SoCal (Thomas Fire-Montecito Debris Flow, Rye, Creek, Skirball, & Lilac Fires).
- Flexible Adaptation Approach is helpful in planning
- Vulnerabilities can vary dramatically by system (i.e. SDGE vs. SCG)

Questions?