Climate Change and Infrastructure Vulnerability Assessment

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Guiding Principles for Today's Workshop

- The climate is changing
- Climate change threatens the ability of engineers to safely and effectively design infrastructure to meet the needs of Canadians
  - Calls into question current rules and design standards
  - Design, operation and maintenance practices must adapt
- Climate change engineering vulnerability assessment is one tool to aid in the adaptation process

Public Infrastructure

"Those facilities, networks and assets operated for the collective public benefit including the health, safety, cultural or economic well-being of Canadians, whether operated by government and/or non-government agencies".

Engineering Vulnerability

"The shortfall in the ability of public infrastructure to absorb the negative effects, and benefit from the positive effects, of changes in the climate conditions used to design and operate infrastructure."

Vulnerability is a function of:

- Character, magnitude and rate of change in the climatic conditions to which infrastructure is predicted to be exposed;
- Sensitivities of infrastructure to the changes, in terms of positive or negative consequences of changes in applicable climatic conditions; and
- Built-in capacity of infrastructure to absorb any net negative consequences from the predicted changes in climatic conditions.
- Vulnerability assessment will, therefore, require assessment of all three elements above.

Part 1

PRINCIPLES OF INFRASTRUCTURE CLIMATE CHANGE RISK ASSESSMENT

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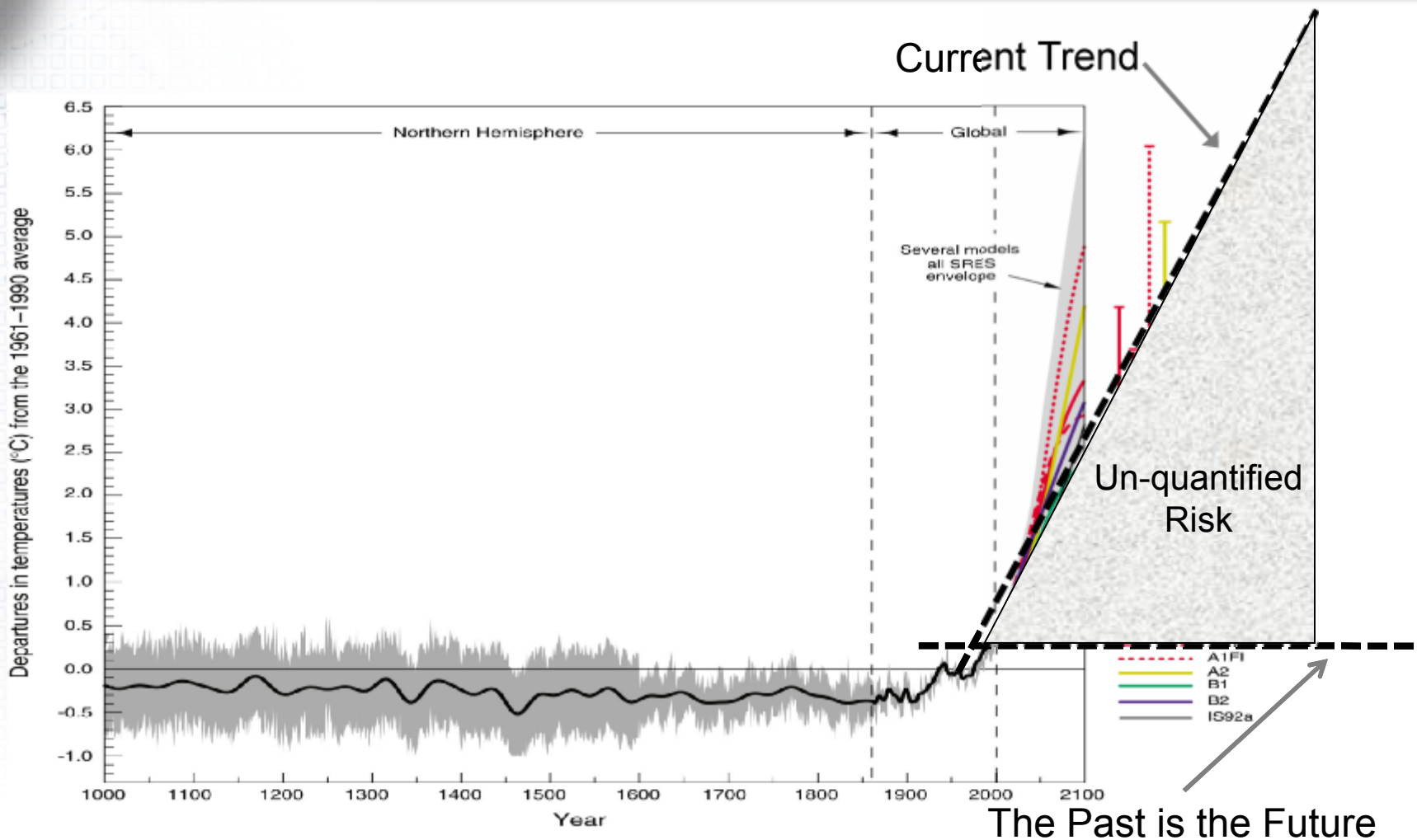
Three Things That Engineers Believe

- The past predicts the future
- Scientific principles always apply
  - Thermodynamic laws don't change
  - Newtonian physics is constant
- Problems can be solved with logical reasoning
  - The physical world is not irrational
  - Observed phenomena can be explained

However …

- The past IS NOT the future
- Scientific principles must be applied in the proper context
- Solving problems using logic only works when our assumptions are correct

The Past IS NOT the Future



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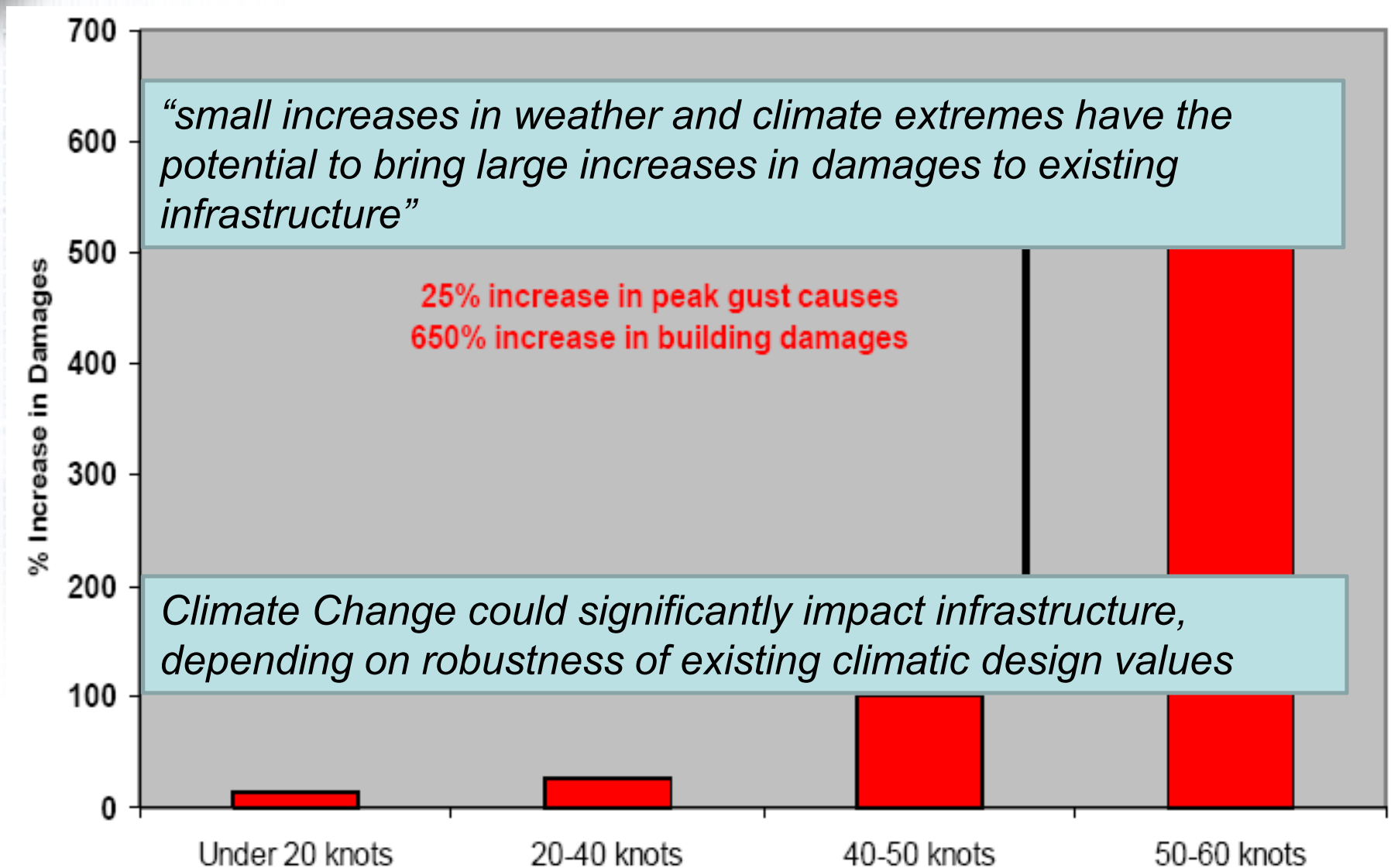
Small Increases = Escalating Infrastructure Damage



"small increases in weather and climate extremes have the potential to bring large increases in damages to existing infrastructure"

Climate Change could significantly impact infrastructure, depending on robustness of existing climatic design values

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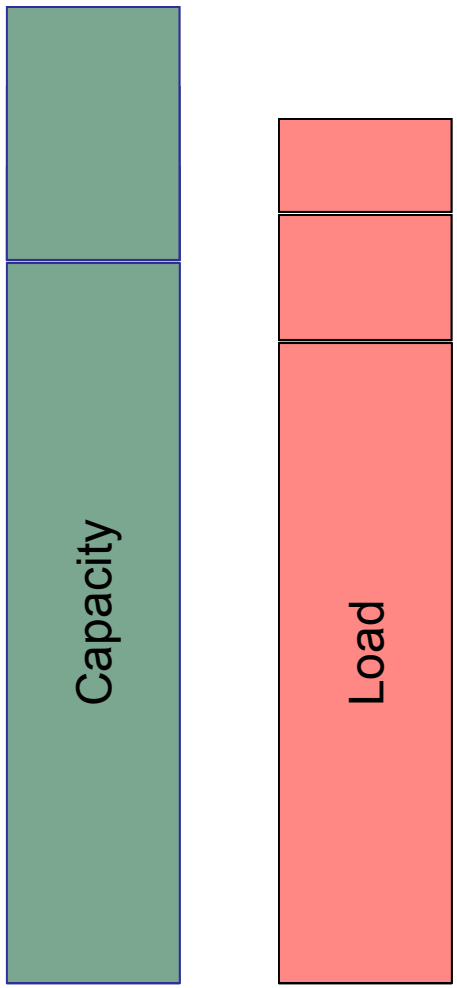
How do Small Changes Lead to Catastrophic Failure?????

Failure

- Design Capacity
- Safety Factor
- Impact of age on structure
- Impact of unforeseen weathering

- Design Load
- Change of use over time
    - For example – population growth
- Severe climate event

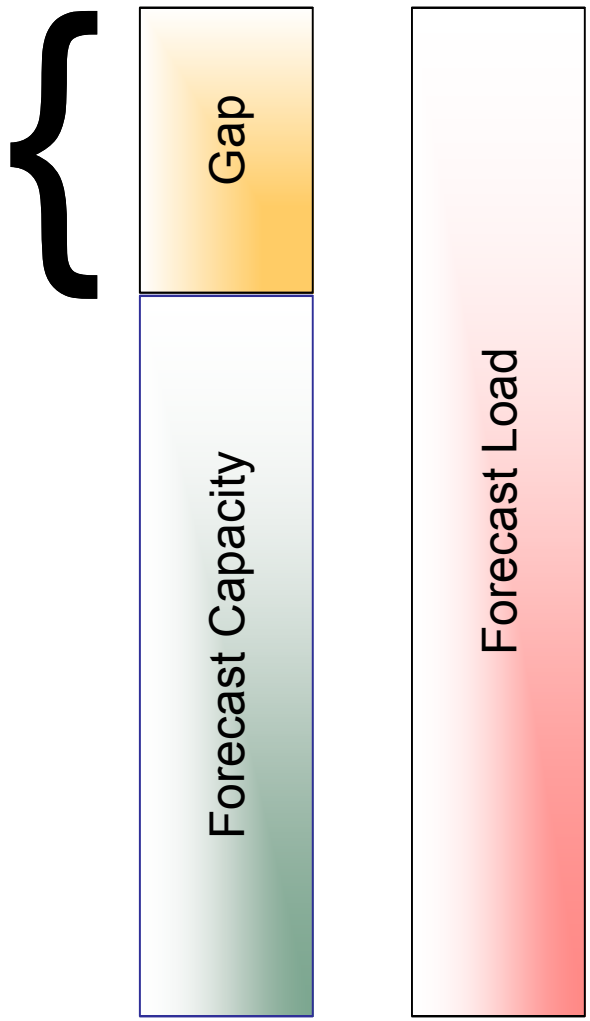


Some Observations

- A small change can have a dramatic impact
- Design safety margins may not last through the full operational life of an infrastructure system
  - Margins may be consumed by day-to-day uses/activities
- Failure often arises from a combination of events
  - Many of which we do not normally monitor
- Climate change can affect both the load and capacity of a structure
- Smaller measures can mitigate risk if we act early
  - Changes in maintenance practice
  - Measuring and monitoring

What is Vulnerability???

Vulnerability

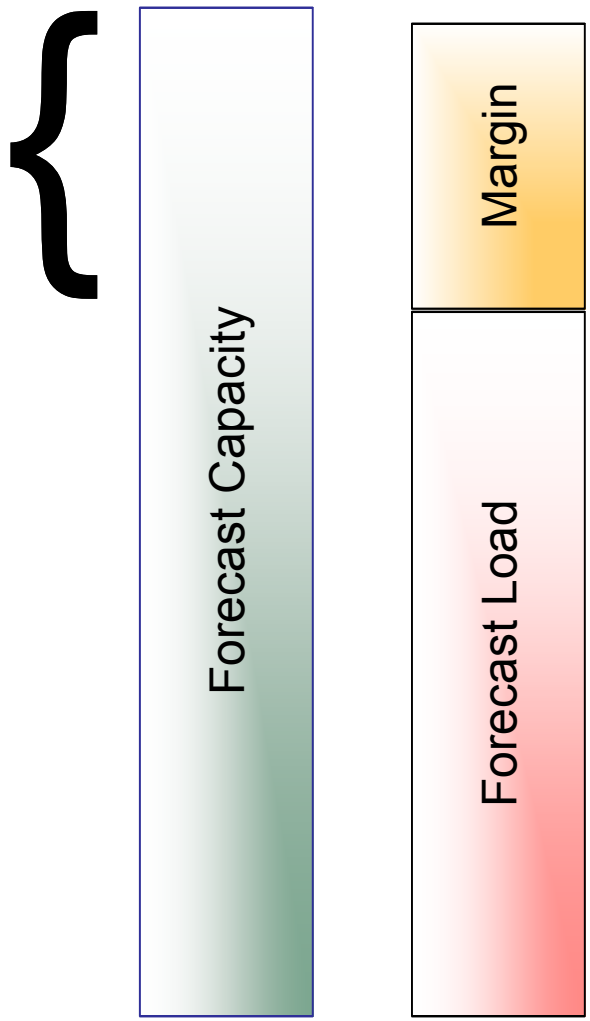


- Engineering design forecasts both the load and capacity of a structure
- If we predict a gap between forecast capacity and forecast load we identify a potential future failure condition
- Such a gap is called an “engineering vulnerability”

What is Resiliency???

Resiliency

- If we can predict a safety margin between forecast capacity and forecast load we identify a potential future non-failure condition
- Such a margin is called “engineering resiliency”



How can we assess vulnerability / resiliency?

- The PIEVC Protocol leads practitioners through a formal, documented, process to identify vulnerabilities and resiliency

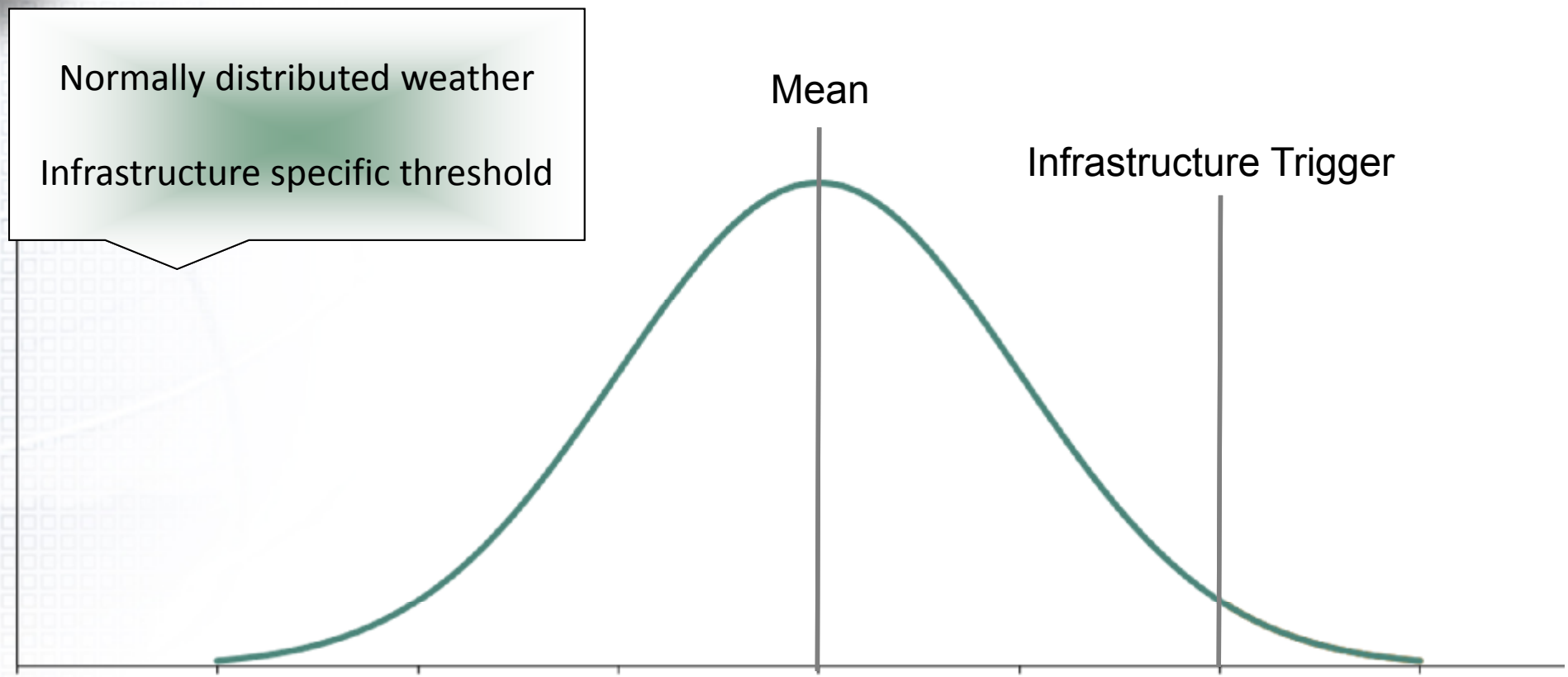
- Applies standard risk assessment processes to this new concern

Small Changes – Big Impact
Another Perspective

There is a relationship between average climate conditions and infrastructure response

Small changes in average conditions can lead to very significant increases in undesirable infrastructure outcomes

Current Distribution of Observed Weather Data



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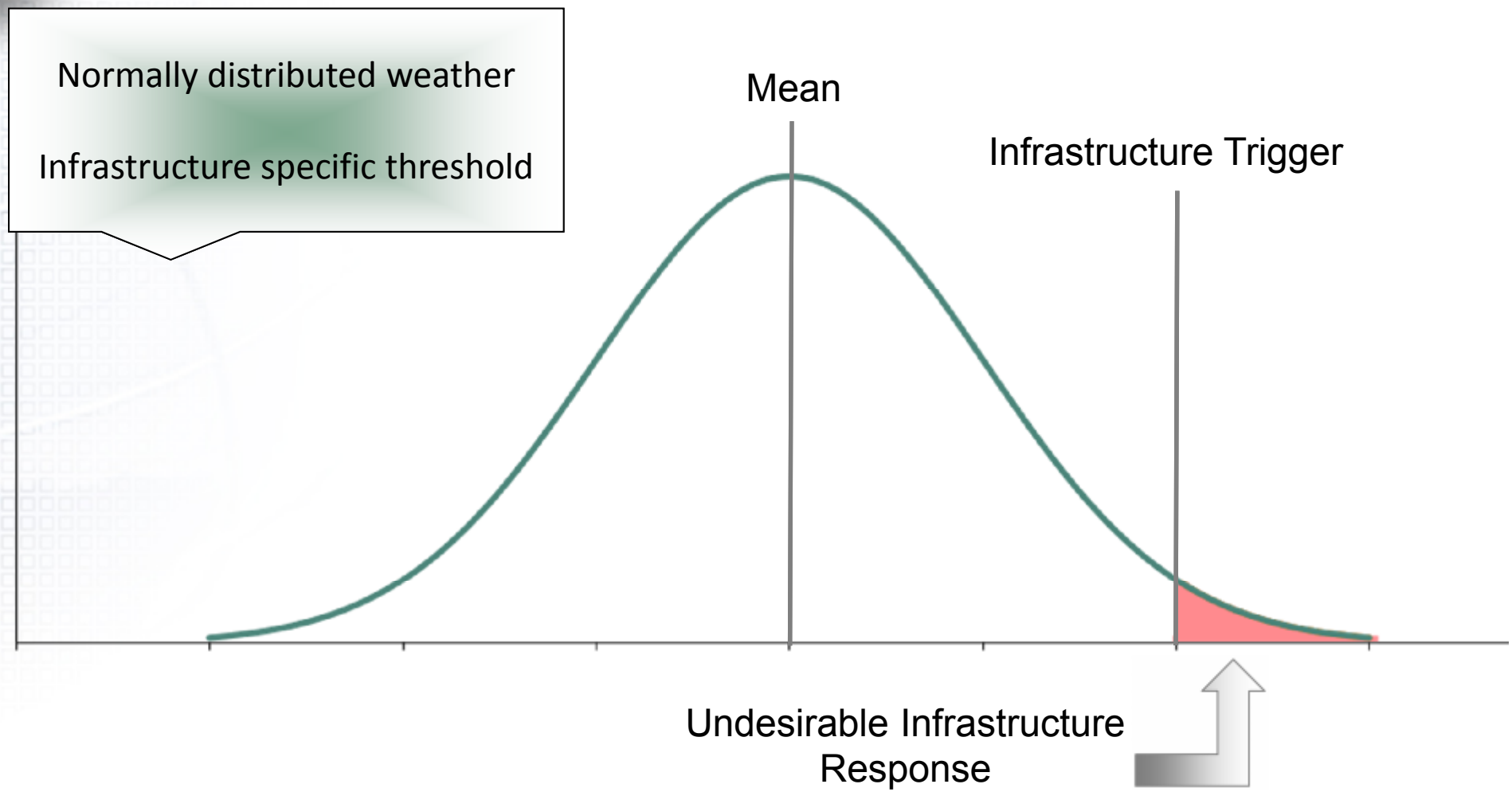

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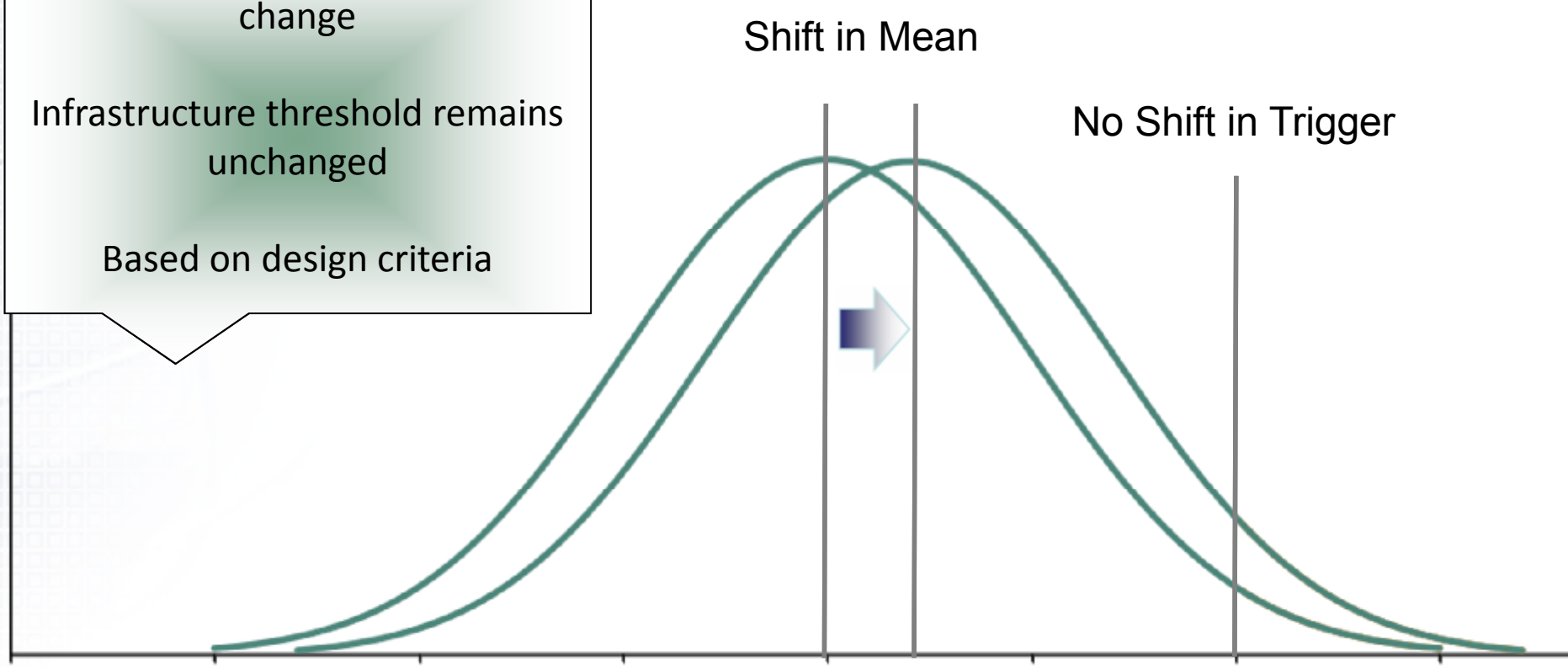
Impact of Climate Change on Mean

Mean value shifts due to climate change

Infrastructure threshold remains unchanged

Based on design criteria



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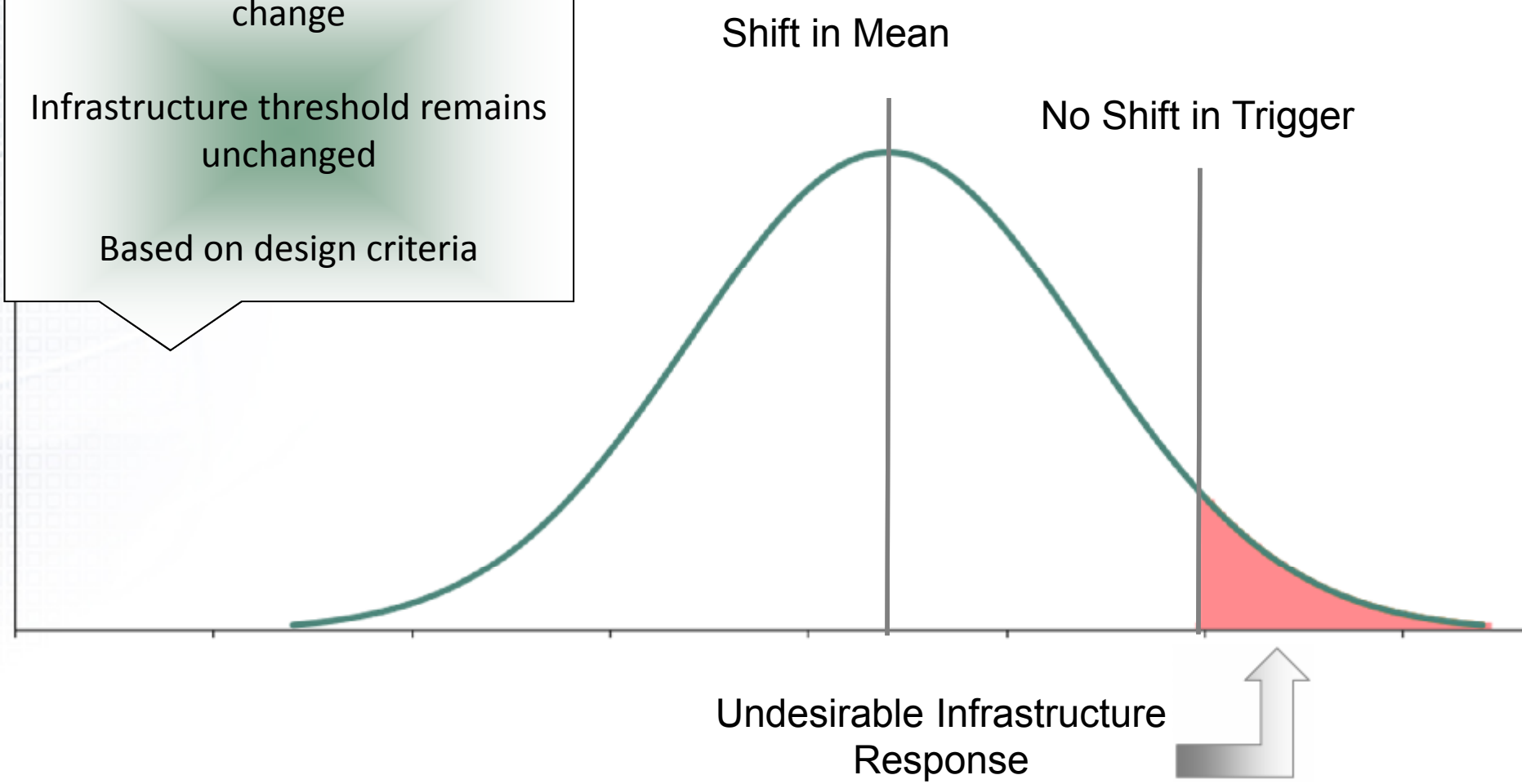

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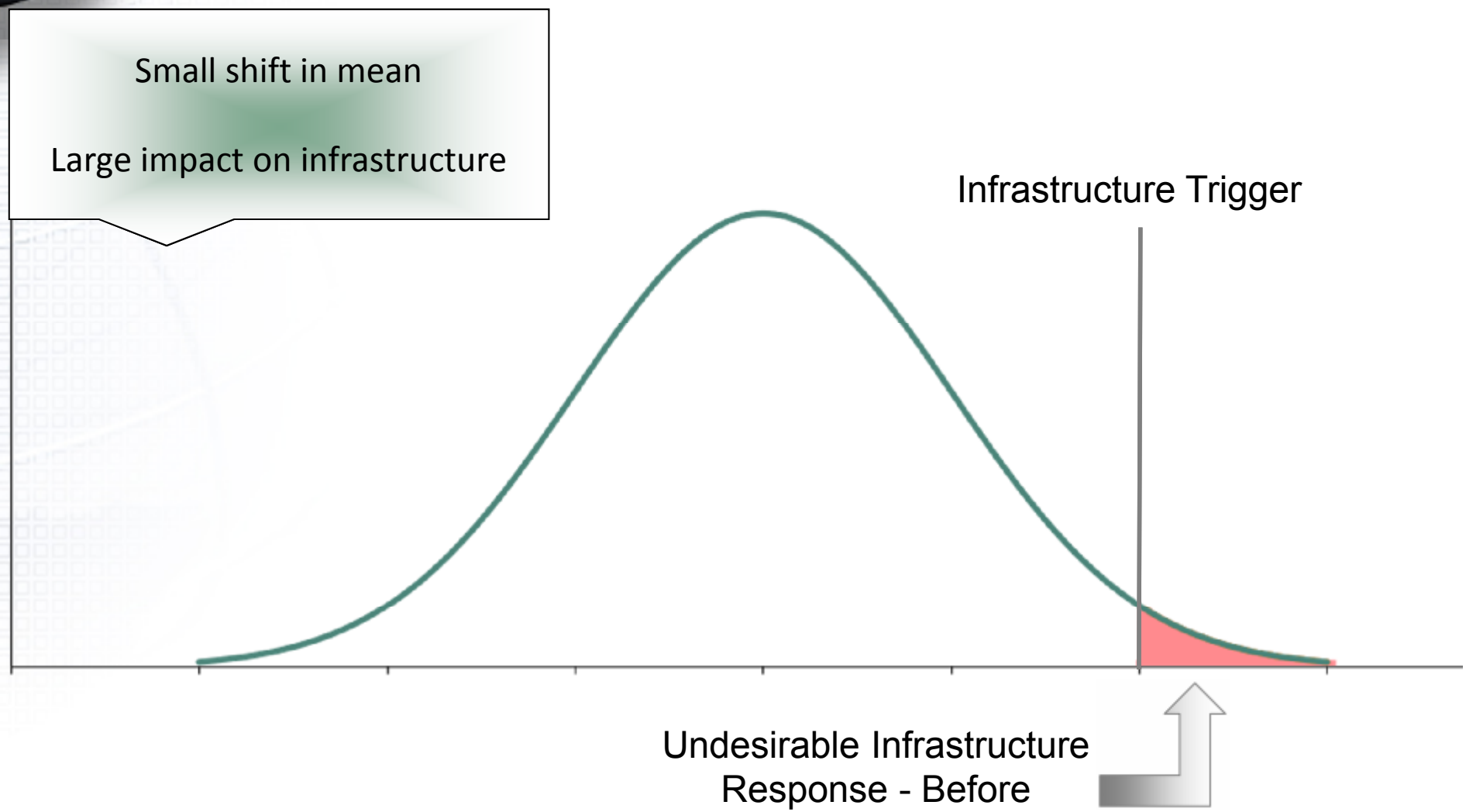
Large Impact on Infrastructure Response



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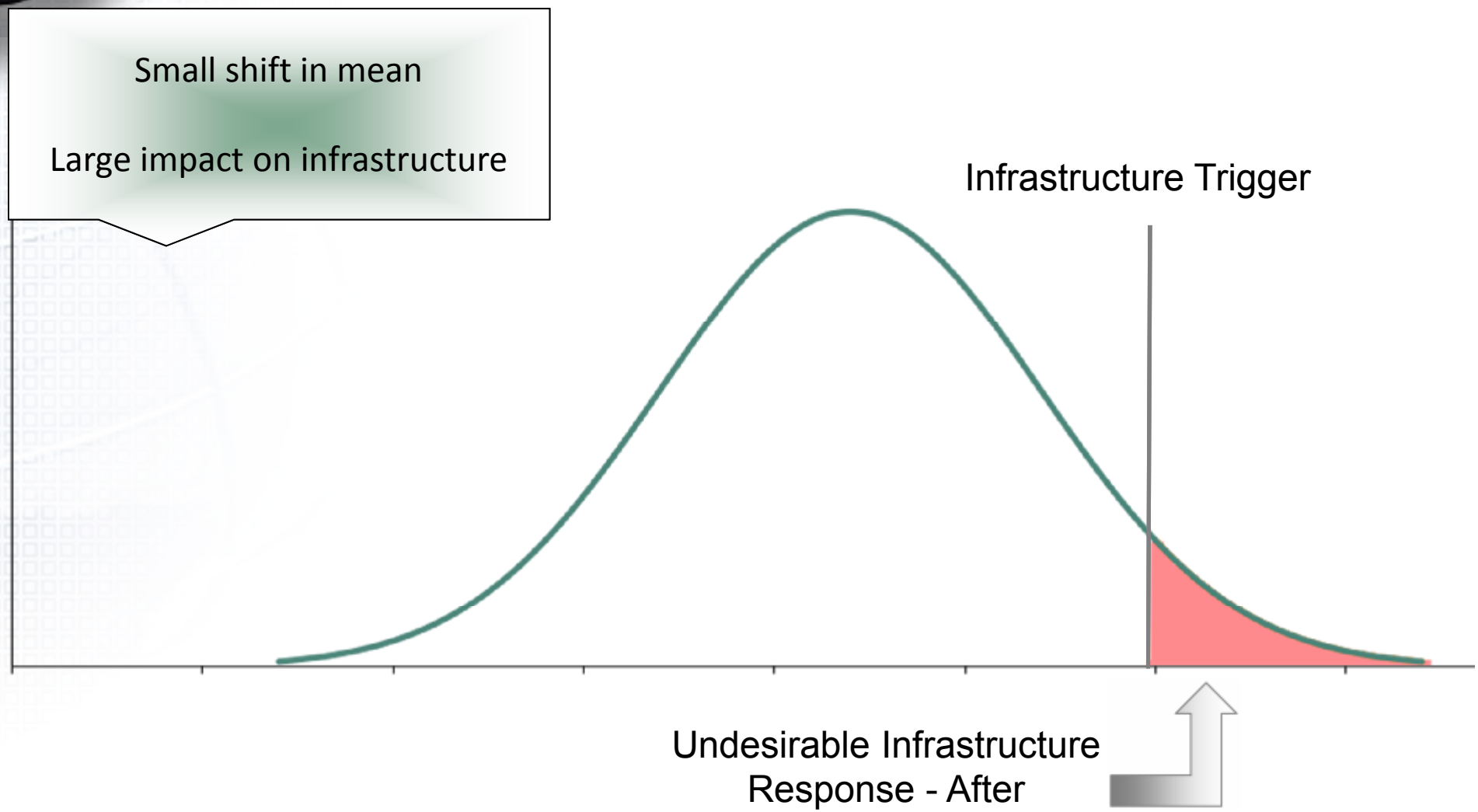

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Summary

- Shift from 20 to 22 represents a 10% increase in mean value
- Area of undesirable infrastructure response doubles in size
  - 100% increase in frequency of weather events triggering undesirable infrastructure responses.
- If we see two such events in a decade now we will likely see four such events in the future.

More Observations

- Vulnerability assessment is predictive
- We are contemplating POTENTIAL failure modes based on forecast information
- But how much confidence do we have in the prediction?
- In order to effectively address the issue we need to assess:
  - The likelihood of the event
  - The level of service disruption
- Without this assessment there is insufficient context to properly manage the issue

$\Rightarrow$ RISK ASSESSMENT

No Need to Discard the Past

- The past can be used to predict the future when:
  - Based on an accurate understanding of the historical record
  - Appropriate application of scientific analysis
  - Assumptions that have been verified with real world observations and experience
- Simply extending the historic record foreword does not predict future events:
  - Simplistic
  - Risky
- New tools are needed to quantify and manage the risk

Quantifying the Risk

- Risk assessment tools and techniques help us quantify risk
- The PIEVC Engineering Protocol is one such tool
- But what do we mean by RISK?

Defining Risk

Risk (R) is defined as the product of the probability (P) of an event and the severity (S) of that event – *should it occur.*

$$R = P \times S$$

Defining Risk

- Since risk is the combined effect of probability and severity ***both*** elements must be considered
  - Very low likelihood and high severity can still be a serious risk
  - Very high likelihood and low severity may be a very low risk
- Most people have an intuitive understanding of risk but need guidance to sort out and assess the relative significance of:
    - Likelihood
    - Severity
- The protocol guides practitioners through the process of assessing both probability and severity in a rigorous manner

Questions?

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