Resilience Metrics for Energy Systems

Henry H. Willis

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RAND JUSTICE, INFRASTRUCTURE, AND ENVIRONMENT

Resilience is a complex concept

A Framework for Establishing Critical Infrastructure Resilience Goals
National Infrastructure Advisory Council
October 19, 2010

There are many ways to define resilience

- For today, it is not important to debate
  - How terms relate
  - Where terms overlap
- Most important to understand
  - What system is being measured
  - What properties are of interest
  - What audiences seek metrics
  - What decisions are made using metrics

Guidelines for measuring resilience

- Resilience describes the state of service from a system in response to a disruption
- Metrics should be selected based on who is measuring resilience and why

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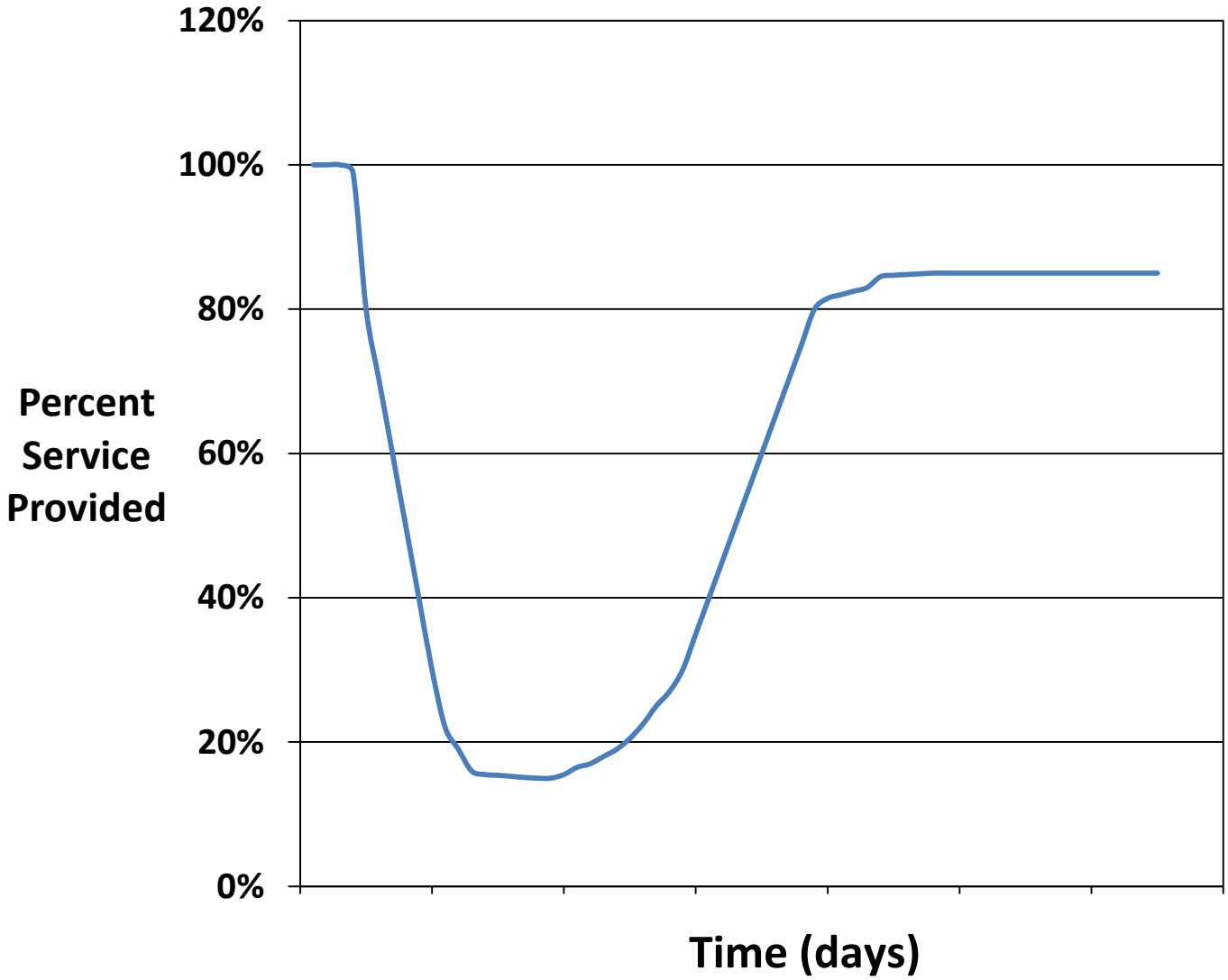
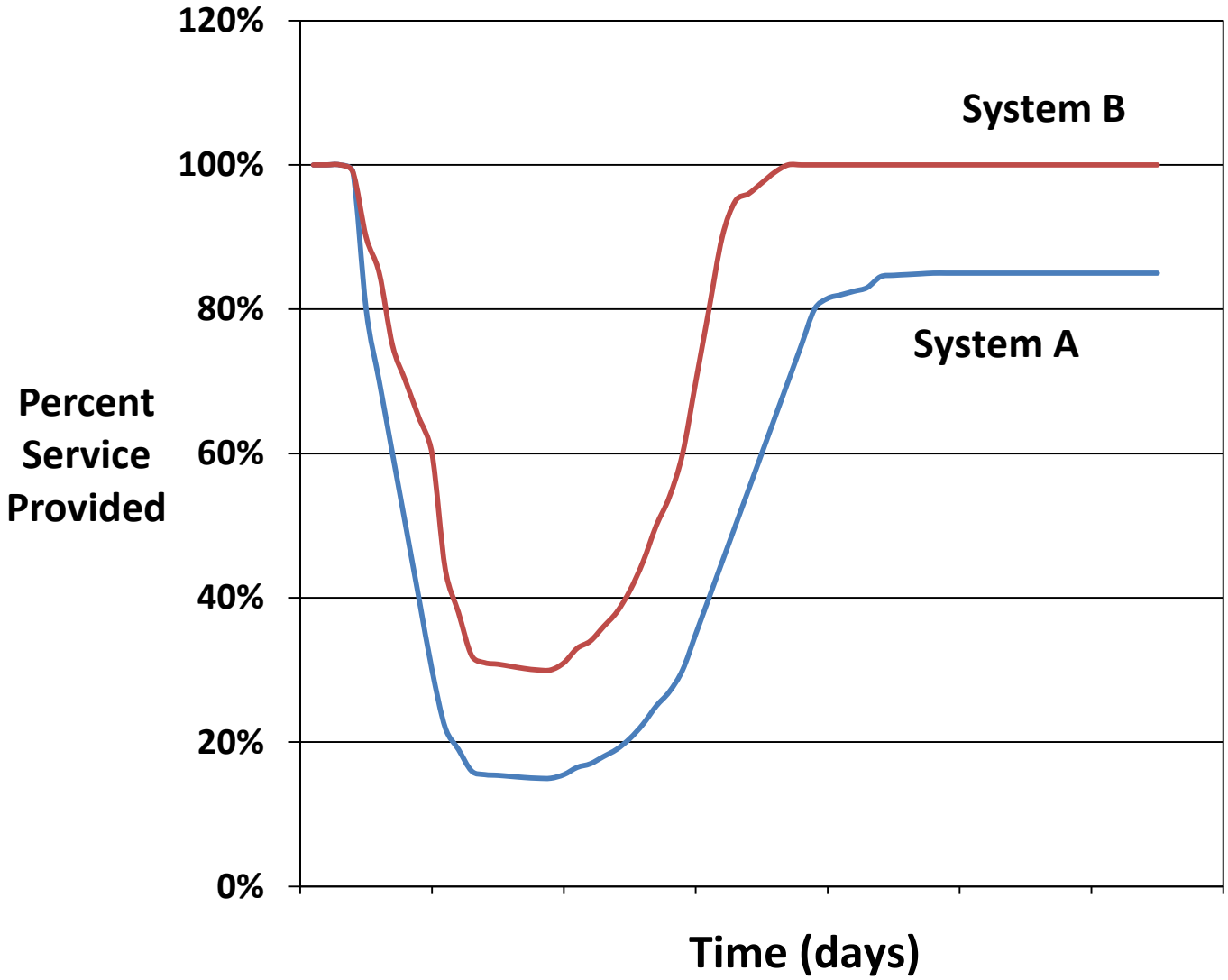


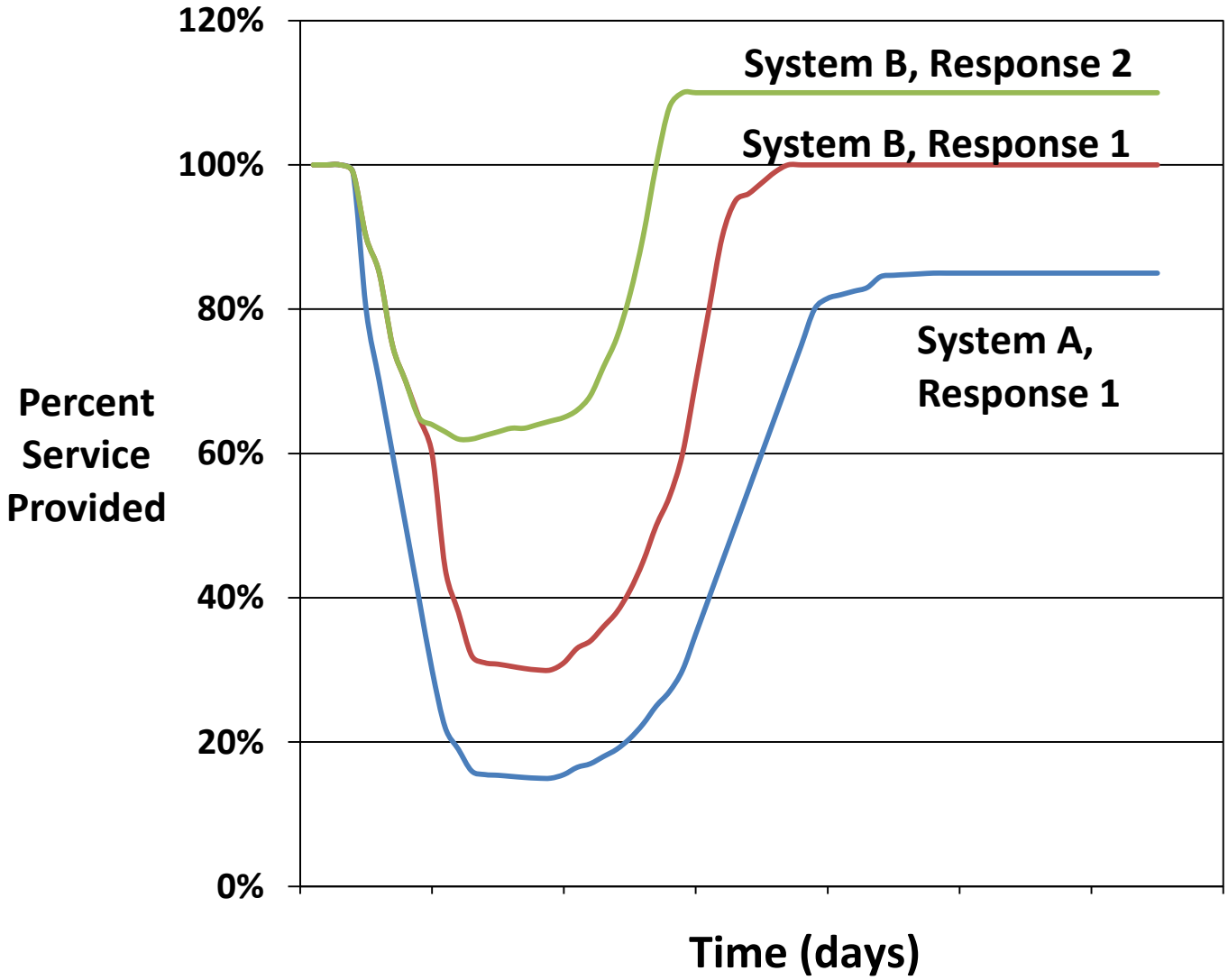
Resilience depends on…

- Type of service
  - Line workers to a response
  - Power to a community
  - Transportation for commuters
  - Income to a region
- Type and extent of disruption
  - Pandemics, hurricane, floods, earthquake, geomagnetic storms, cyber attacks, events now and in the future
- System design, operation, and response
  - Redundancy
  - Maintenance
  - Response

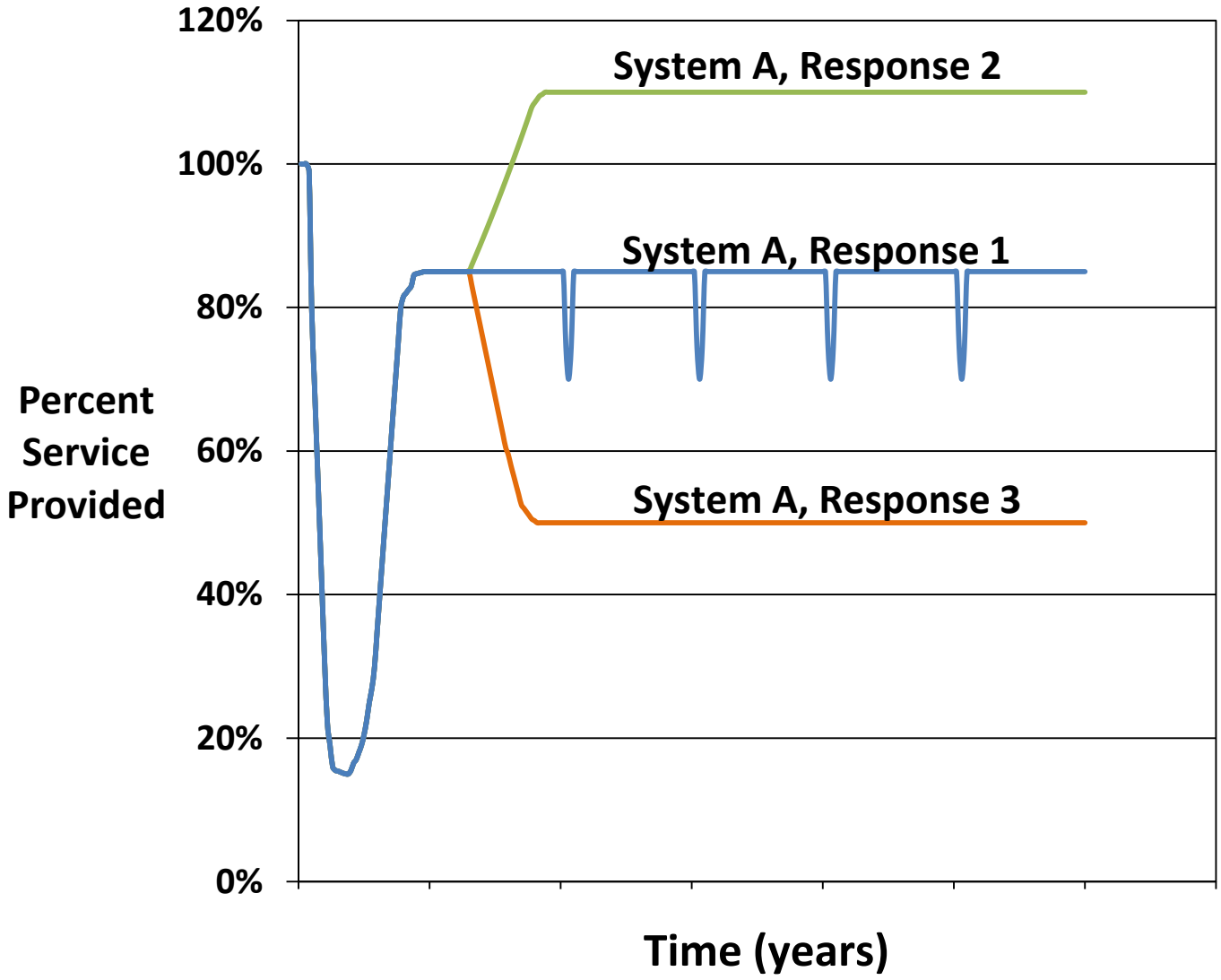
Different systems will have different resilience to the same disruption



Different responses will lead to different resilience at different costs



Resilience of a system also depends on the time scale considered



Guidelines for measuring resilience

- Resilience describes the state of service from a system in response to a disruption
- **Best metrics depend on who is measuring resilience and why**

Resilience metrics are used for many purposes and at many levels

Inputs

What is available?

Examples
- Budgets
- Equipment
- # of spare parts
- # of generators
- # of line workers

Resilience metrics are used for many purposes and at many levels

Inputs	Capacities
What is available?	How are inputs organized?

Examples

- Response teams
- Plans
- Aid agreements
- Smart-grid tech

Resilience metrics are used for many purposes and at many levels

Inputs	Capacities	Capabilities
What is available?	How are inputs organized?	What tasks can be performed?

Examples

- Outage detection
- Line repair
- Backup delivery
- Outage restoration

Resilience metrics are used for many purposes and at many levels

Inputs	Capacities	Capabilities	Performance
What is available?	How are inputs organized?	What tasks can be performed?	What is produced?

Examples

- Energy delivery
- Efficiency
- Reliability
- Hardness
- Robustness
- Sustainability

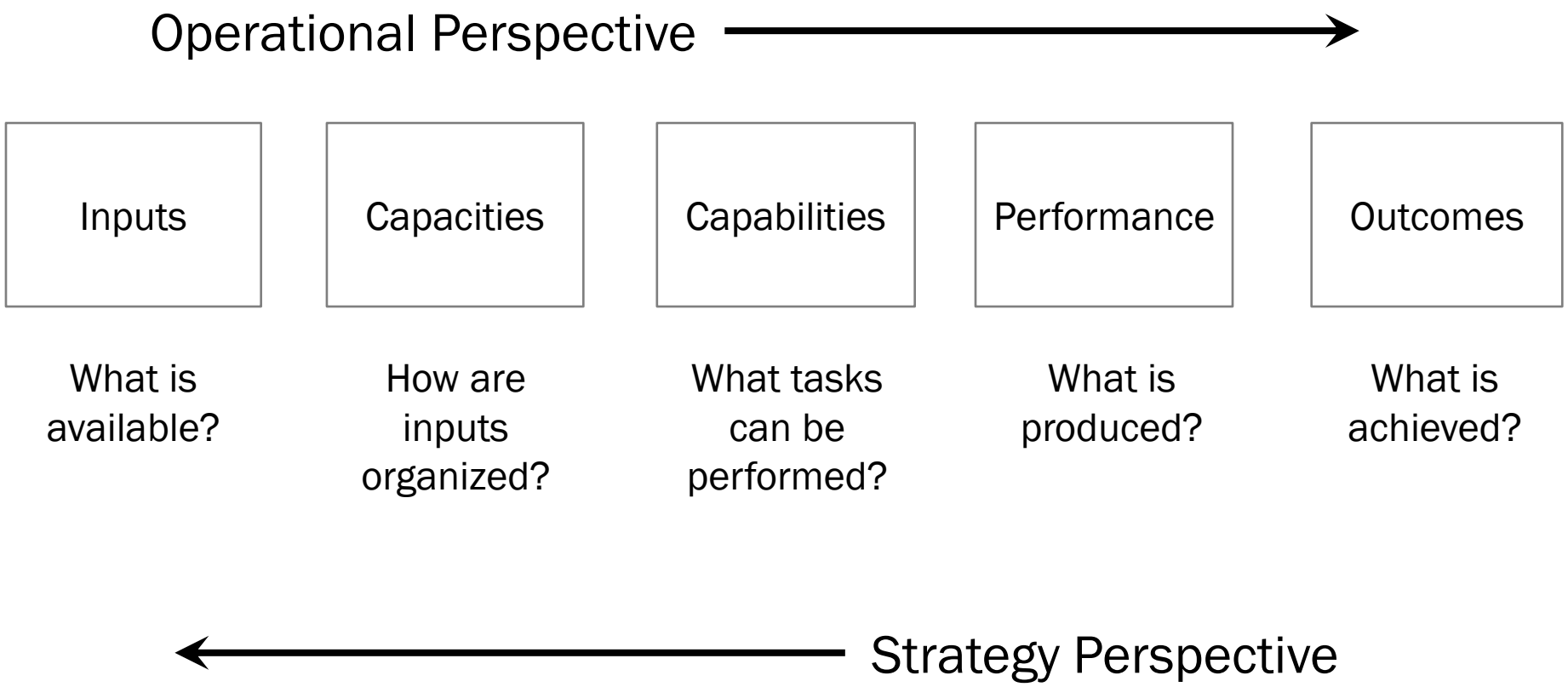
Resilience metrics are used for many purposes and at many levels

Inputs	Capacities	Capabilities	Performance	Outcomes
What is available?	How are inputs organized?	What tasks can be performed?	What is produced?	What is achieved?

Examples

- Economic activity
- Costs and damage
- Human welfare

Metrics support both strategic and operational decisionmaking



There is not a single set of metrics for all purposes

Inputs	Capacities	Capabilities	Performance	Outcomes
Examples • Budgets • Equipment • # of spare parts • # of generators • # of line workers	Examples • Response teams • Plans • Aid agreements • Smart-grid tech	Examples • Outage detection • Line repair • Backup delivery • Outage restoration	Examples • Energy delivery • Efficiency • Reliability • Hardness • Robustness • Sustainability	Examples • Economic activity • Costs and damage • Human welfare

Selecting metrics requires balancing validity, reliability, and practicality in as few metrics as possible

Summary

- Resilience can be evaluated for different systems, disruptions, responses, and time-scales
- Metrics can describe inputs, capacities, capabilities, performance, or outcomes
- Metrics must be selected for a purpose
- Selecting metrics requires considering conciseness, comprehensiveness, validity, reliability and practicality

Questions for discussion

- What resilience outcomes are stakeholders most concerned about?
- What are stakeholders' needs for resilience metrics?
- What analysis are you doing that must take resilience into account?
  - In what context (risk assessment, investment analysis, etc.)
  - How are you doing that?
- Are existing metrics adequate?
- What resilience metrics are currently codified in Federal or state regulations, and are they adequate?
- What specific metrics are most useful?

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