Metrics for Energy Resilience

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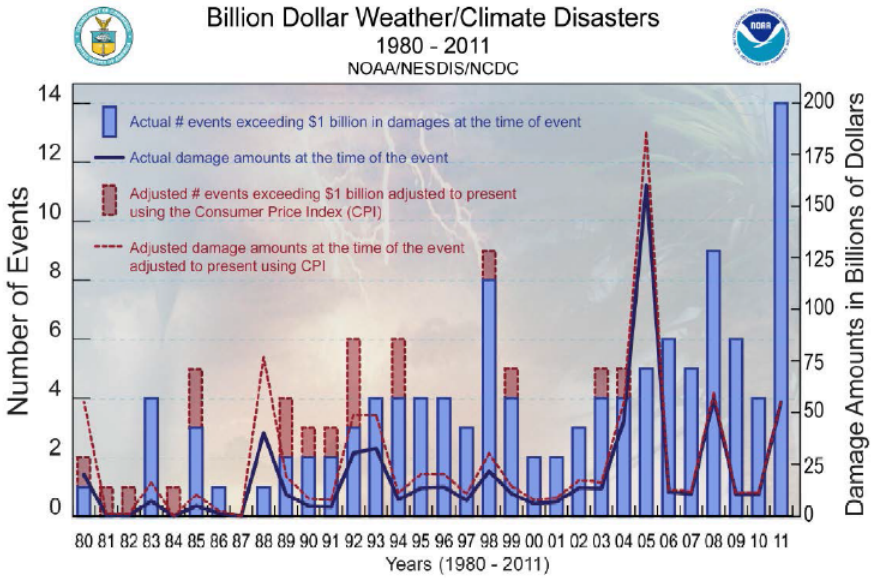
What's wrong with "protection"?

Conventional deterministic/actuarial risk management approaches proving unsatisfactory for modern society

- *Natural events more devastating*
- *Human threats diversifying*
- *Long-term changes unpredictable*
- *Nonlinear utility curves*



Graph source: NOAA National Climatic Data Center, http://www.ncdc.noaa.gov/billions/

Definitions

- "the ability to ***recover*** from or easily ***adjust*** to misfortune or ***change***" *(Merriam Webster 2013)*

- "the ability to ***prepare*** for and ***adapt*** to ***changing*** conditions and ***withstand*** and ***recover*** rapidly from disruptions. . . ." (Presidential Policy Directive 21, 2013).

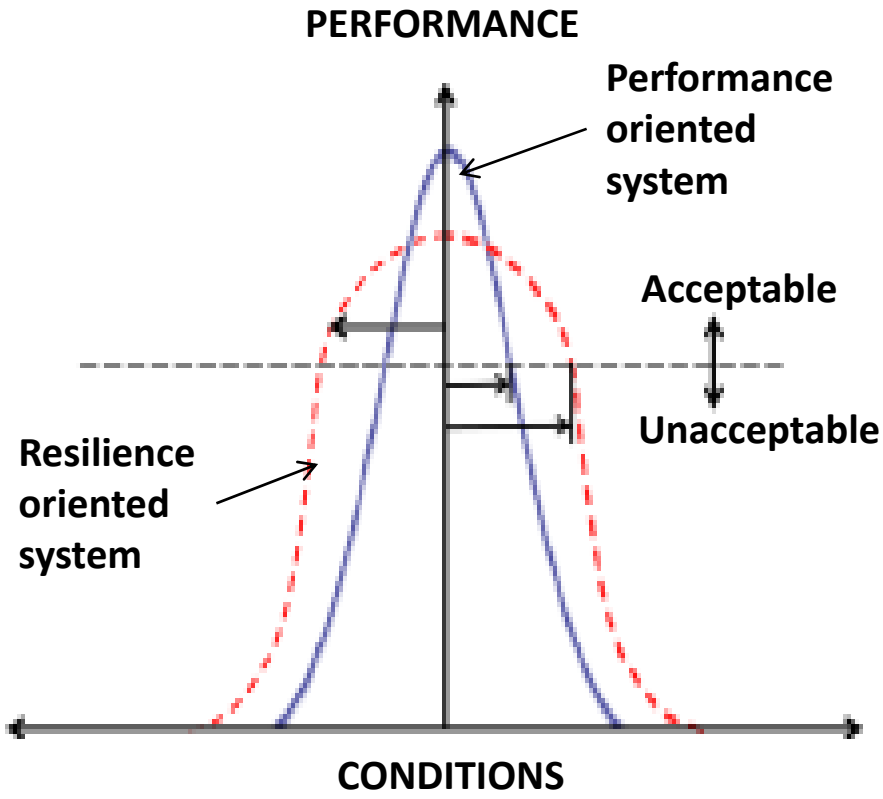
- "the ability to ***prepare*** and ***plan*** for, ***absorb***, ***recover*** from, and more successfully ***adapt*** to adverse events. (National Academy of Sciences 2012).

Transformational Risk Approach

- Orientation about ***response*** to changing conditions
- ***Time***-phased definitions
- Shifting focus from system design to ***outcomes***
- Dynamics involve ***holistic*** community response
- Emphasis on ***adaptation*** vs. restoration

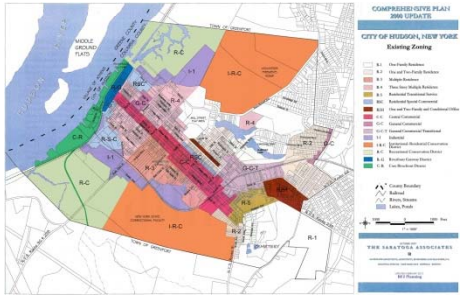
Change Orientation

- **Traditional design**: optimize for ***design conditions***; protect system
- **Resilient design:** design system to meet needs under ***varying conditions***



Time Phases

Prepare



Adapt

Recover

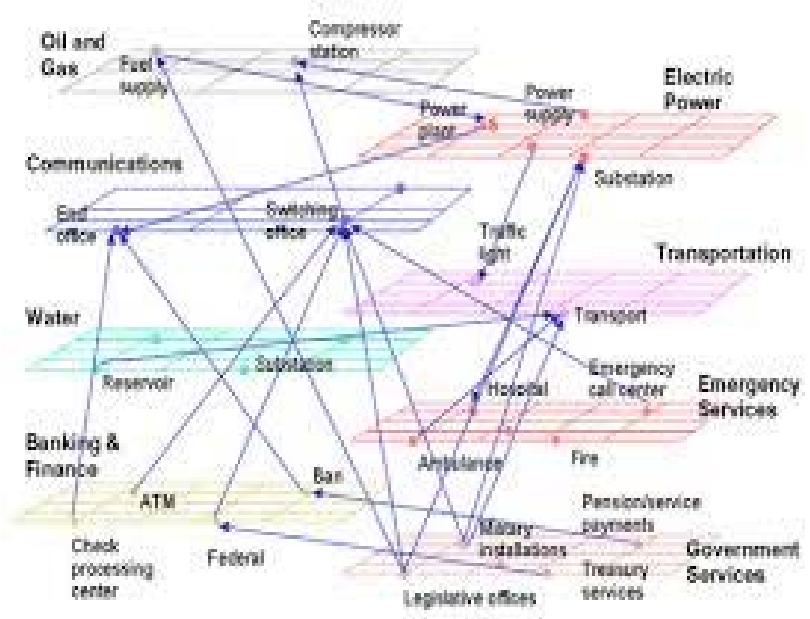
Respond

Outcome Focus

- Withstand vs. maintain
- Flexibility and alternatives

Holistic Community Response

- Deep security, welfare **interdependencies**
- BUT . . . many **stakeholders** independent
- **Multi-domain** approach
  - Physical
  - Information
  - Human
    - Cognitive
    - Social



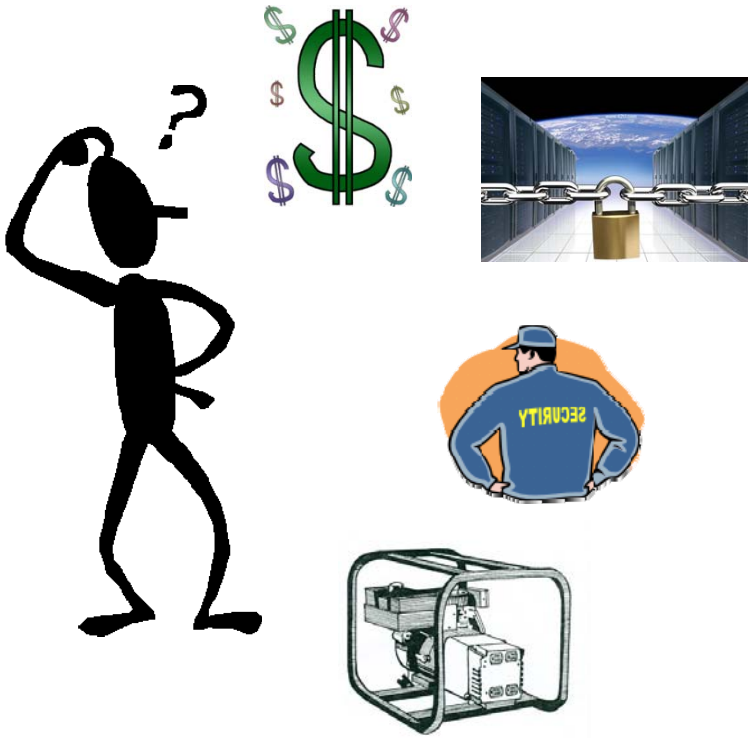
Adaptation

- Learning
- Response to changing conditions
- Relationship between flexibility and adaptability

Decision-making

How do we **value** and resource investments to increase **resilience**?

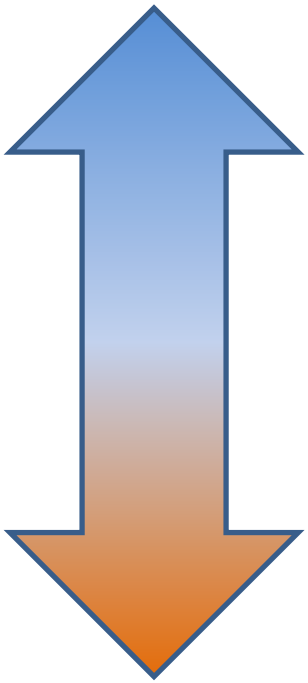
- *Reduced emphasis on specific contingency scenarios*
- *Diverse measures taken by various actors can contribute to outcomes*
- *Value of preparedness increases during and after event*



Hierarchal Application

- National
- Regional
- Community
- System
- Component

Ecological Resilience



Engineering Resilience

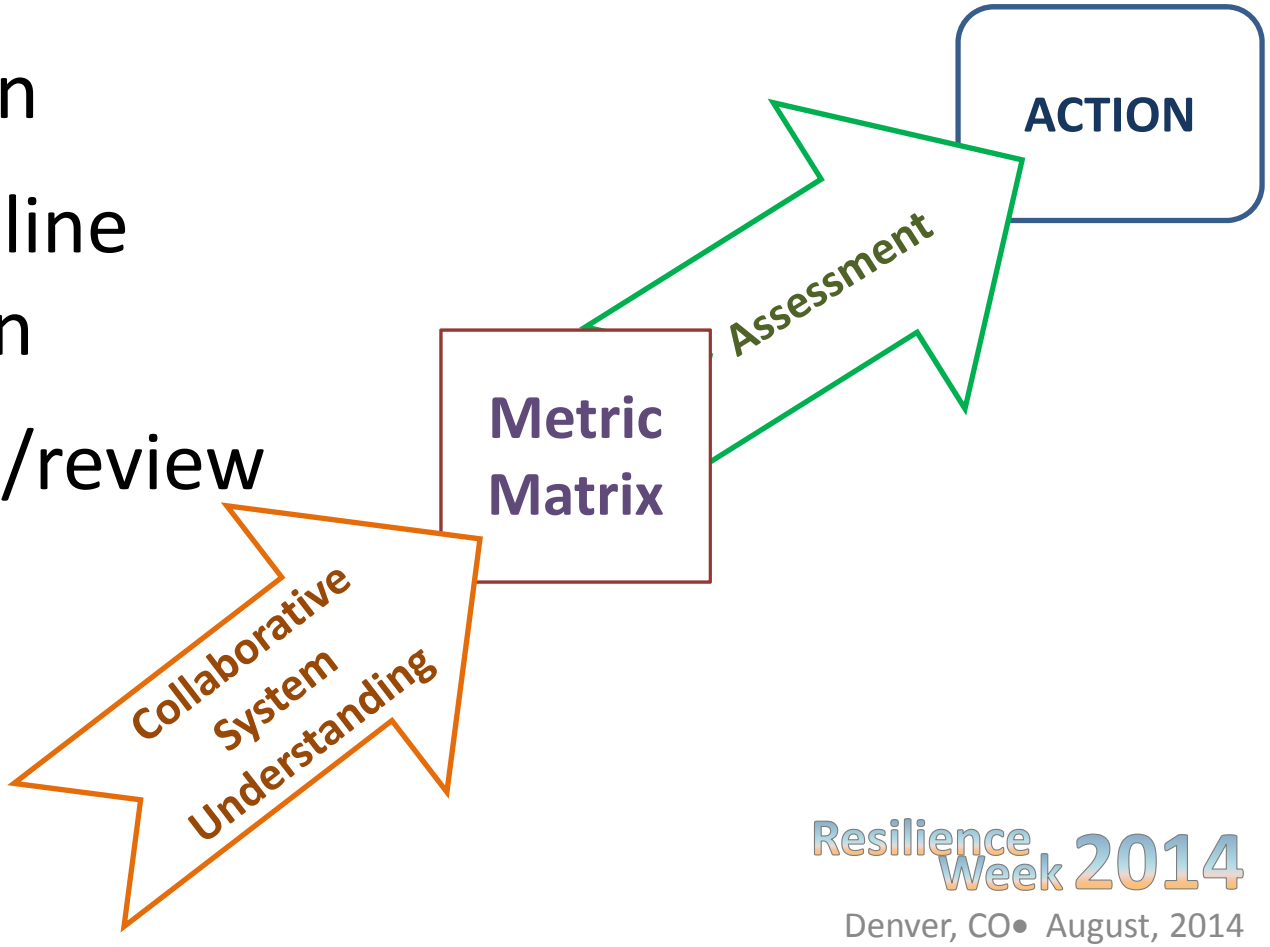
We need a structured way to measure seemingly fuzzy contributions!

Metrics Taxonomy

Phase / Domain	Plan/Prepare	Respond	Recover	Adapt
Physical	Infrastructure, equipment, materials			
Information	Plans, designs, status, directions			
Cognitive	Knowledge, memory, judgment, attitude,			
Social	Regulations, policies, business processes, valuation			

Utilization

- Investment decisions
- Prioritization
- Cross-discipline coordination
- Assessment/review



Recommendations

- Cultivate **stakeholder** discussion to expose important **outcomes** and system interactions;
- Build **agreement** on **value** measurement through resilience matrix development;
- Utilize matrix as an evolving tool for **portfolio decisions, communications, learning**.