1.5. Panel Discussion: DEFINING, MEASURING, AND ASSIGNING RESILIENCE REQUIREMENTS

Dr. Alexander Zhivov, ERDC CERL

Mr. Andrew Stringer, USACE Power Reliability Enhancement Program

Mr. John Benefiel, Protective Design – Mandatory Center of Expertise

October 13, 2020

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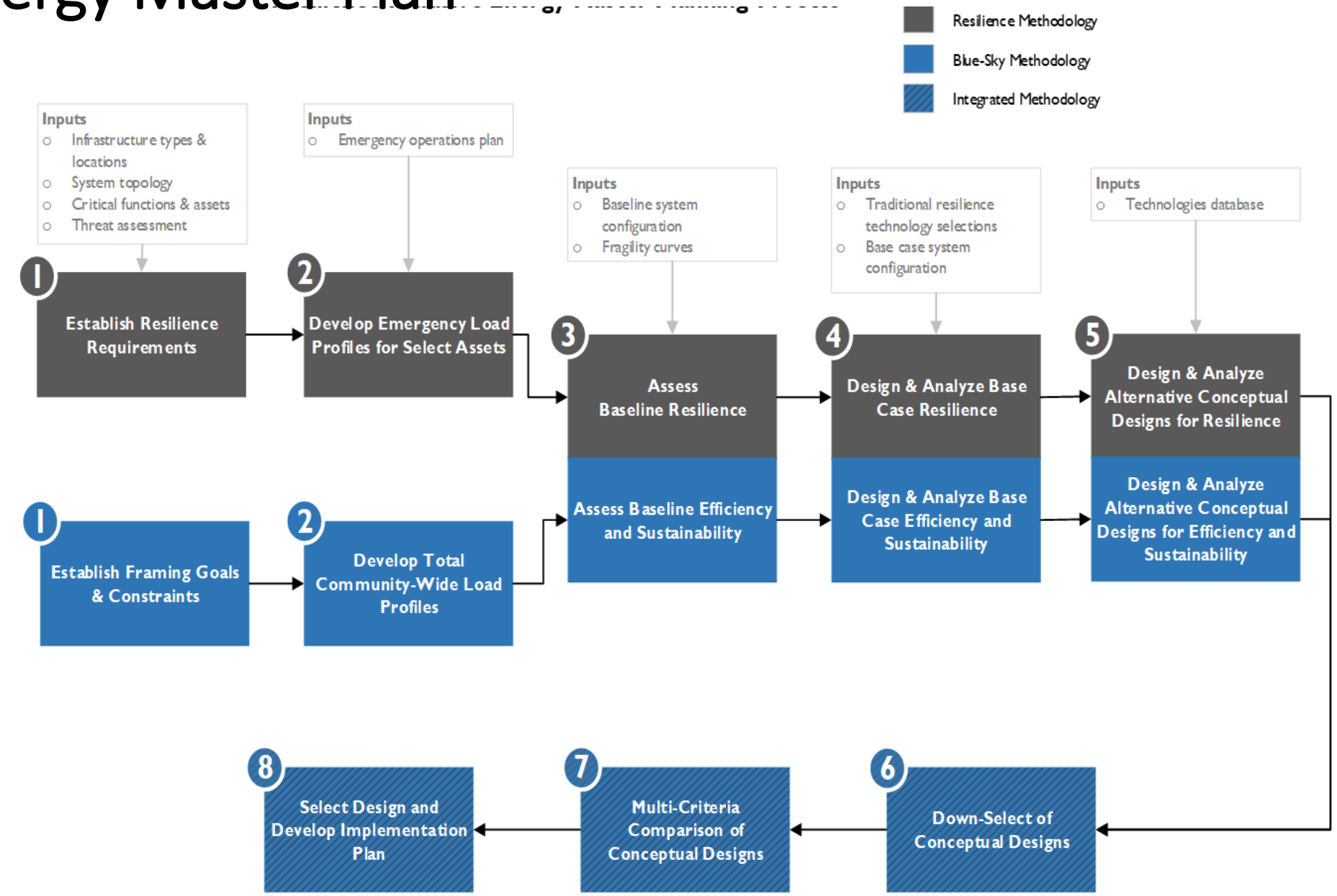
- Mr. John Benefiel, Chief - Security Engineering Section, Protective Design–Mandatory Center of Expertise (PDMCX), USACE, Omaha District

Integration of Energy Systems Resilience Analysis into Energy Master Plan



Energy system resilience

- A resilient energy system is one that can prepare for and adapt to changing conditions, and recover rapidly from disruptions including deliberate attacks, accidents, and naturally occurring threats (PPD-21, U.S. Army 2015).

Quantifying energy system resilience

The proposed quantitative approach supports DoD memorandum [DoD, 2020] and include (but not limited to) the following metrics:

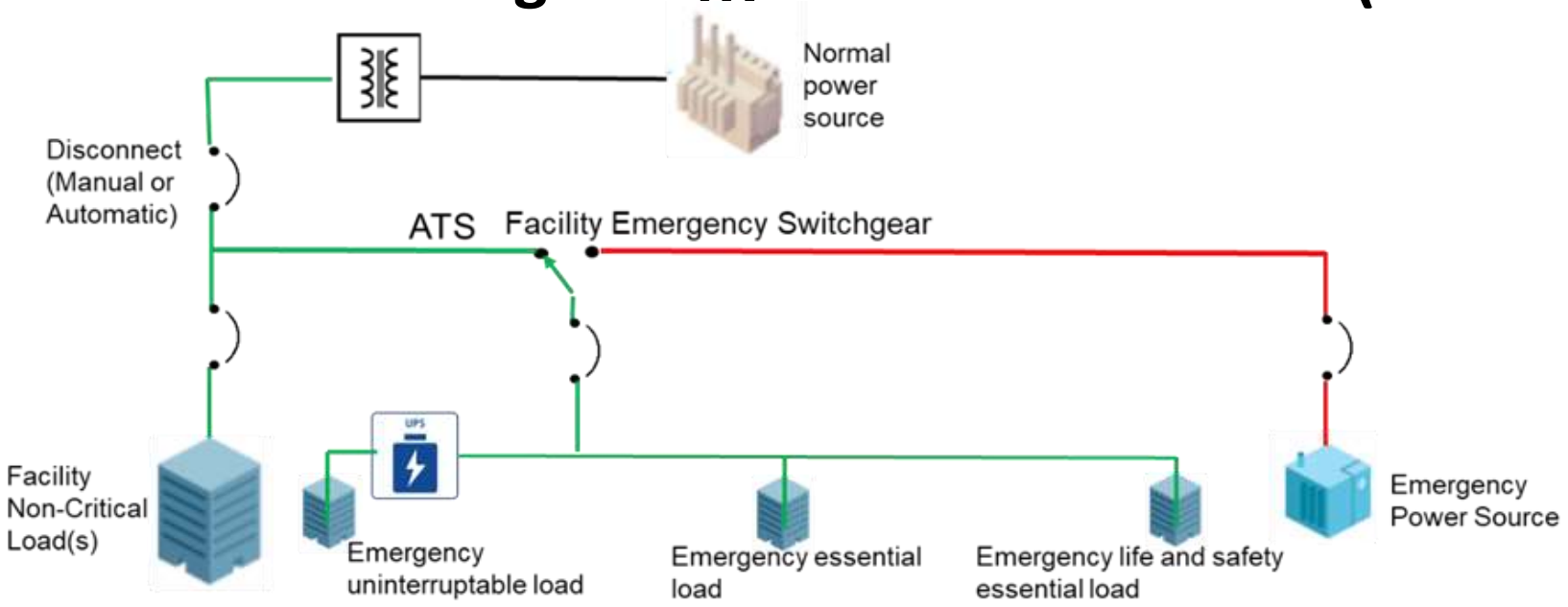
- **Energy System Robustness (ER)**
- **Energy System Recovery time**
- **Energy Availability (EA)**
- **Energy Quality (EQ).**

- The first three parameters are critical for selection of the energy supply system architecture and technologies it is comprised of to satisfy requirements related to energy system resilience;
- Most of the mission specific energy quality requirements (both electric and thermal), including the level of tolerance to short-term interruptions, can be handled by the building-level energy systems (electric nano-grids), or building thermal systems (that include the building envelope, thermal storage and HVAC system), which are designed based on class or tier of such requirements.

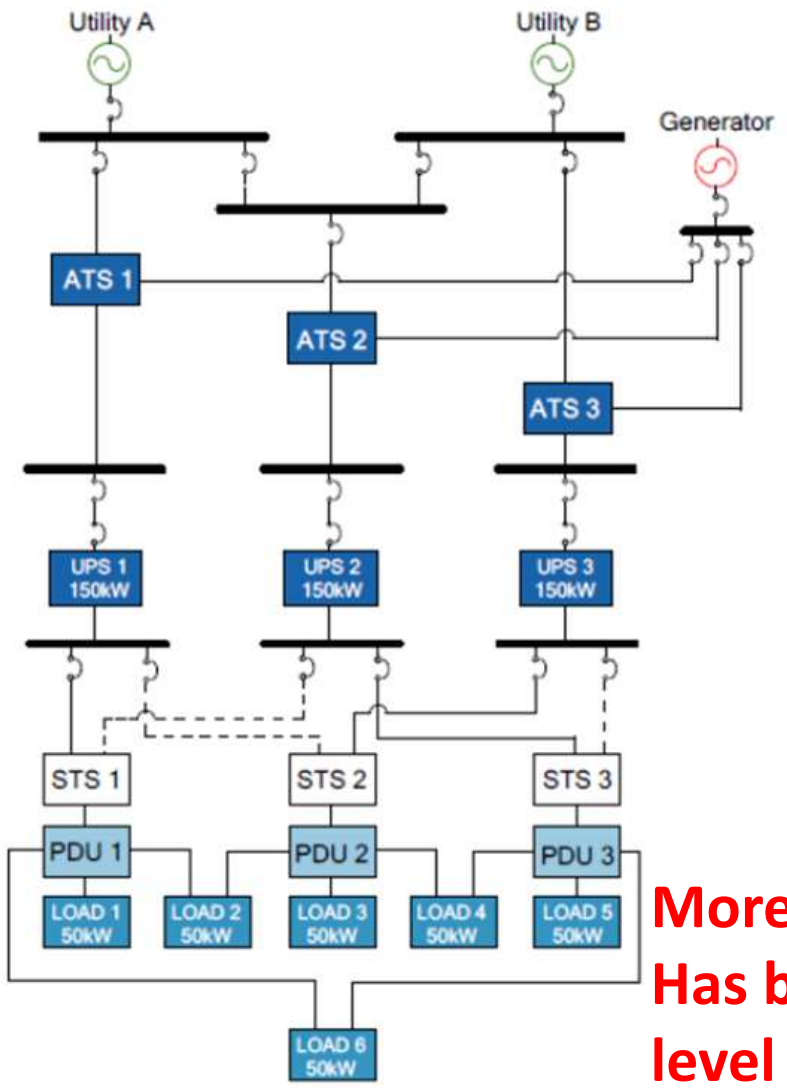
Energy System Robustness

Requirements for Energy Robustness depend on a load that is critical to the mission during emergency (Black-Sky) conditions and that can be measured as the percentage of the:

1. **Total mission essential load requirements**
2. **Overall building energy load under normal (Blue-Sky) conditions**



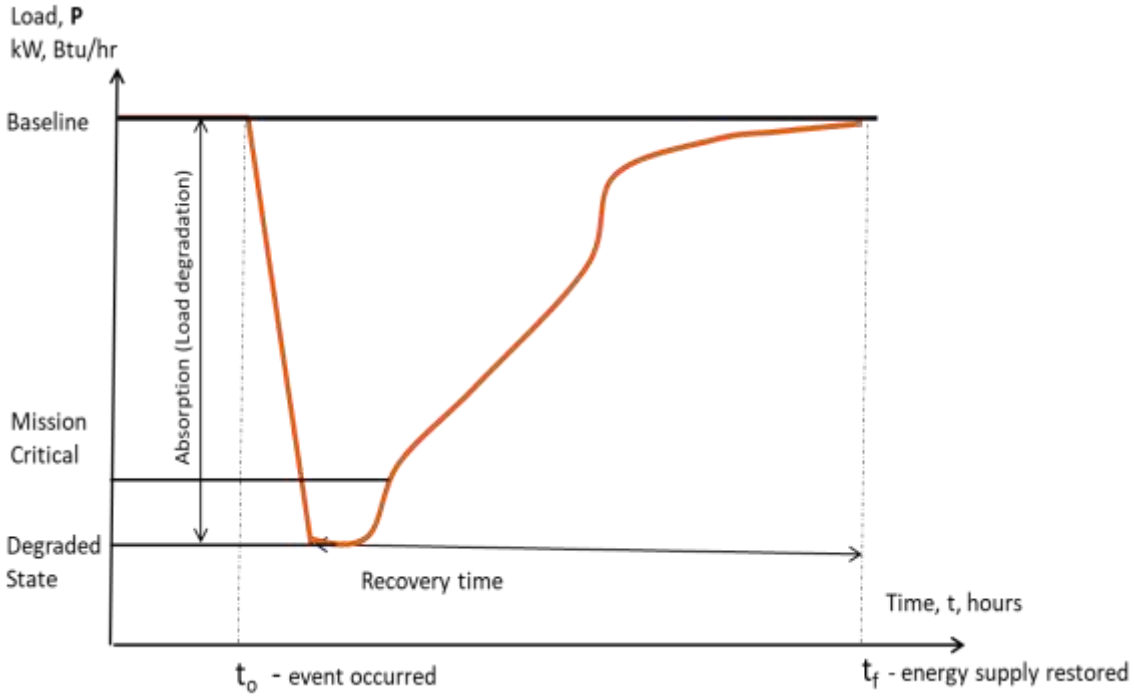
Energy Quality



Energy Quality is another important quantitative metric for the energy system that serves critical functions; energy quality should be considered as a design parameter for internal building energy systems. Most of the mission-specific energy quality requirements, including limitation on short-term power interruptions, voltage and frequency variations, harmonics, etc. (see Performance Class Transient Limits in Unified Facilities Criteria (UFC) 3-540-01 [NAVFAC 2019]) can be handled by the building-level energy systems.

More details about building level electric systems (nano-grids) Has been presented during the Session 1.4; buildings and building level thermal systems will be discussed on Thursday, October 15 during the Session 3.

Energy System Robustness



Robustness is defined as "the ability to absorb shocks and continue operating" (NERC). In many critical facilities, there may be many mission assets that are considered uninterruptible, critical but interruptible, and life- and safety-related. Since it is imperative to the mission that these assets remain online, any undelivered load to such facilities or assets would be considered a mission failure. Energy Robustness is a metric that shows power availability, P (in kW and/or kBtu/hr), to satisfy critical mission loads over a period of time immediately following the event, measured as a fraction of the mission-critical requirement or as a fraction of the baseline energy requirement.

$$R_{m.c.} = \frac{E_{event}}{E_{m.c.}}$$

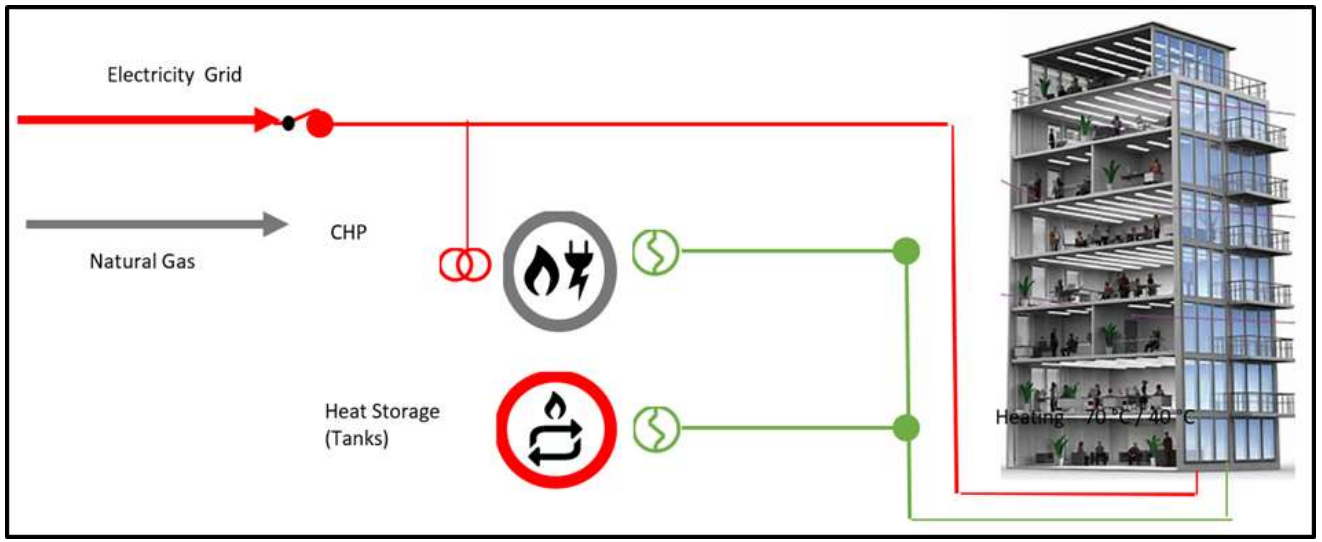
$$R_{baseline} = \frac{E_{event}}{E_{baseline}}$$

$$E = \int_{t_o}^{t_f} P(t)\,dt$$

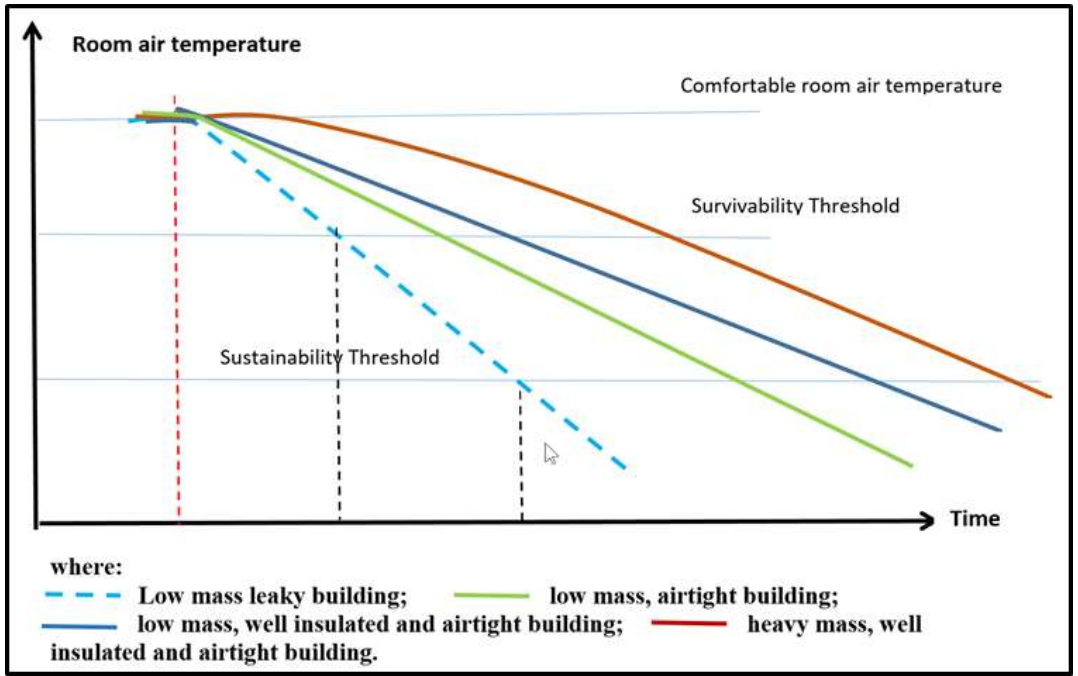
$R_{m.c.}$ and **$R_{baseline}$** = system robustness against the mission-critical load and the baseline load;

E_{event}, **$E_{m.c.}$**, and **E_{event}** = energy supplied to the building during the period between t_o and t_f with the baseline load, mission-critical load and degraded due to event load

Maximum time to repair of the thermal system



Notional example of temperature decay rate for different types of building envelope.



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