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Innovation & Resilience: Navigating Grid Modernization Challenges

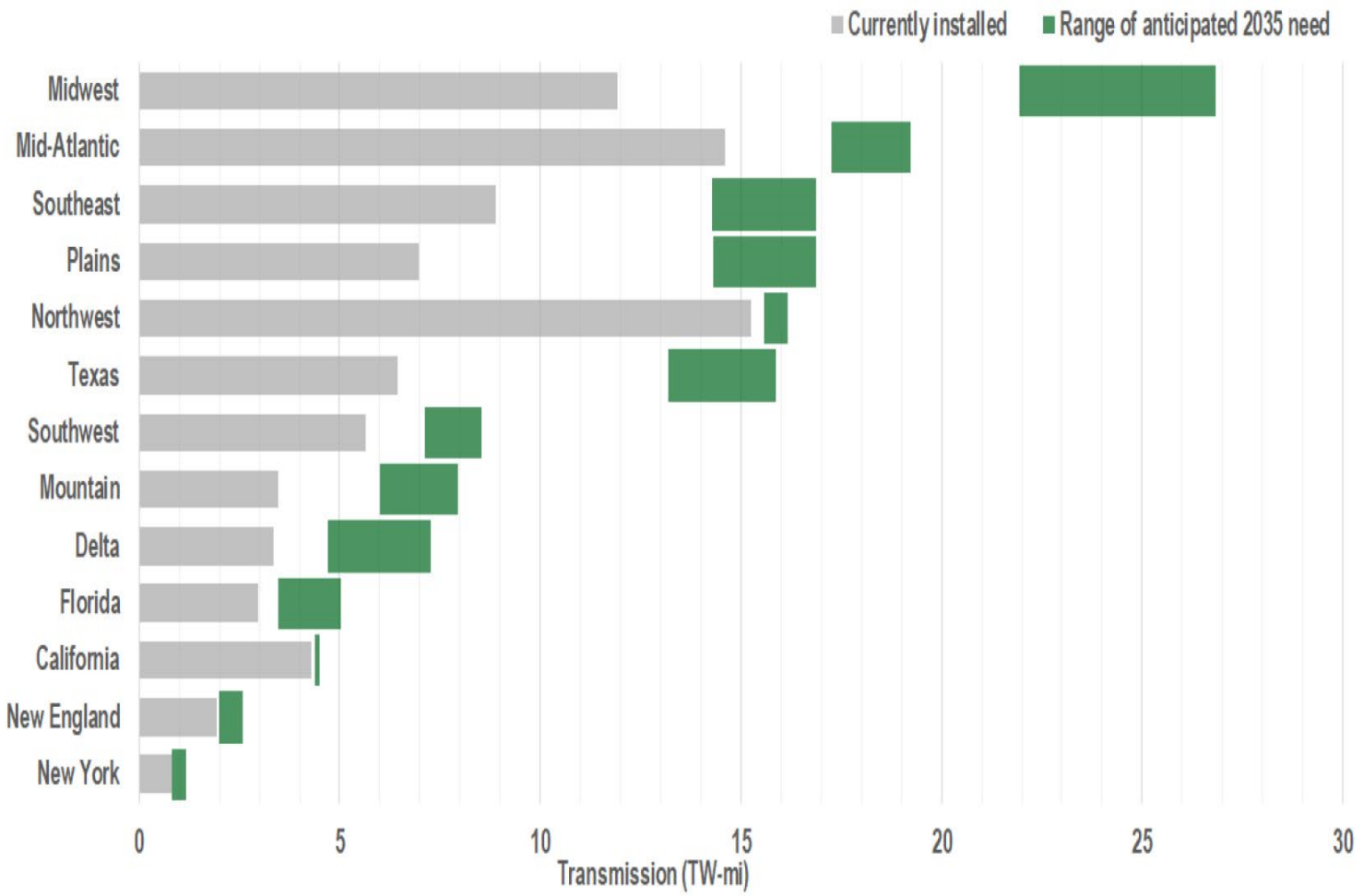
Battelle Energy Alliance manages INL for the
U.S. Department of Energy's Office of Nuclear Energy

INL Idaho National Laboratory

A Congested Outlook: Integrating Clean Energy

- ***Grid Transmission Capacity --*** Aging power infrastructure needs to be replaced or augmented in order to meet the increased demand for power.
- ***Adding more Clean Energy Generation --*** Clean energy will address the need for clean and sustainable energy but must be integrated into the existing power grid.
- ***Geography Matters --*** Renewable energy sources are often located far from load centers, requiring extensive transmission infrastructure to carry electricity from the generation sites to the consumers.
- ***Slow Rate of Interconnection --*** As more renewable generation sources join the grid, congestion costs are expected to rise substantially.
- ***Cybersecurity concerns –*** Many renewable energy systems haven't yet matured in terms of cyber security risk management and operations because the generation technologies are still in the early stages of deployment and operations.

Transmission Capacity Is Needed

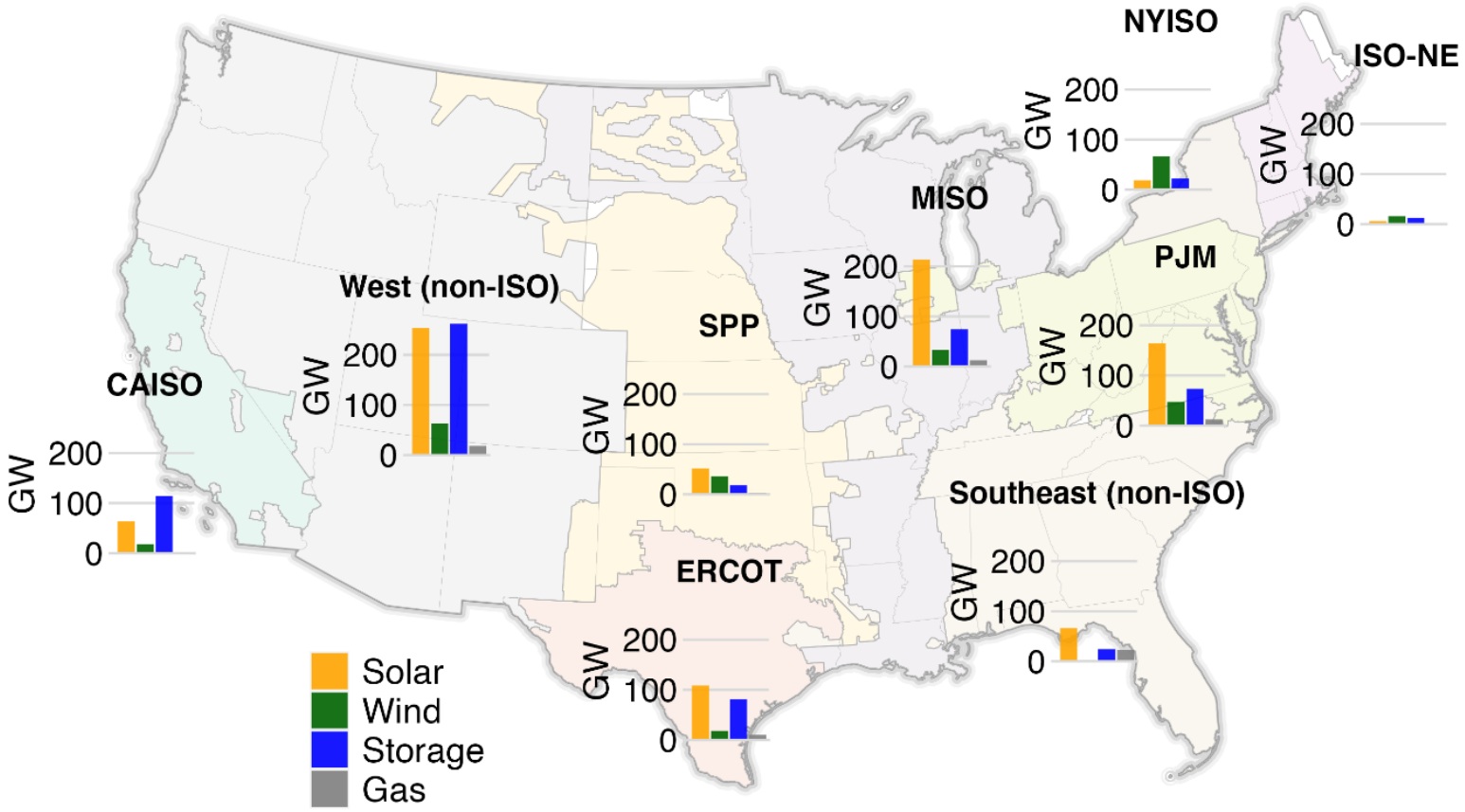


Regional Transmission: Comparison of what exists today to anticipated need in 2035 for ~70% decarbonized power (DOE Needs Study, 2022)

- Key findings from the DOE National Transmission Needs Study (2022):
  - There is a pressing need for additional electric transmission infrastructure.
  - Increasing interregional transmission results in the largest benefits.
  - Needs will shift over time. The clean energy transformation, evolving regional demand, and increasingly extreme weather events must all be accommodated by the future power grid.

Gridlocked: Clean Energy Interconnection Queue

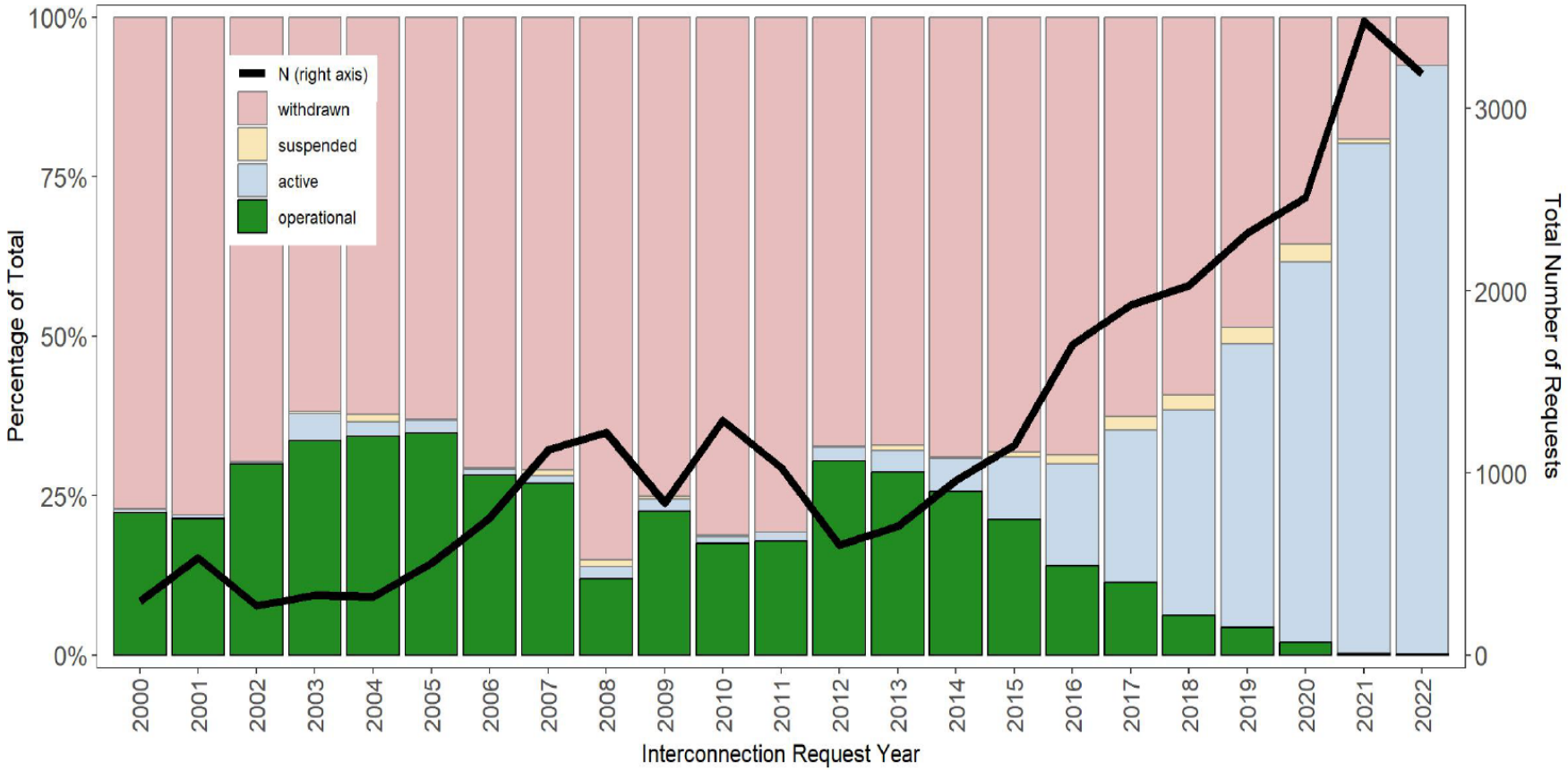
Proposed projects seeking to connect to the grid



- Interconnection is dictated by a complex network of laws, regulations, and administrative processes
- Prospective renewable energy installations are **accumulating an increasingly large backlog**
- Over 2,000 gigawatts (GW) of total generation and storage capacity now seeking connection to the grid
- Current interconnection procedures, however, are **not designed to accommodate** the deployment of the hundreds of gigawatts of
- Amount of solar power, wind energy, and energy storage in the queues today is roughly the **same amount needed to reach 80%** of U.S. electricity from zero-carbon resources by 2030

https://emp.lbl.gov/sites/default/files/queued_up_2022_04-06-2023.pdf

Gridlocked: Clean Energy Interconnection Queue



https://emp.lbl.gov/sites/default/files/queued_up_2022_04-06-2023.pdf

Only 21% of all projects proposed from 2000-2017 had reached commercial operations by the end of 2022

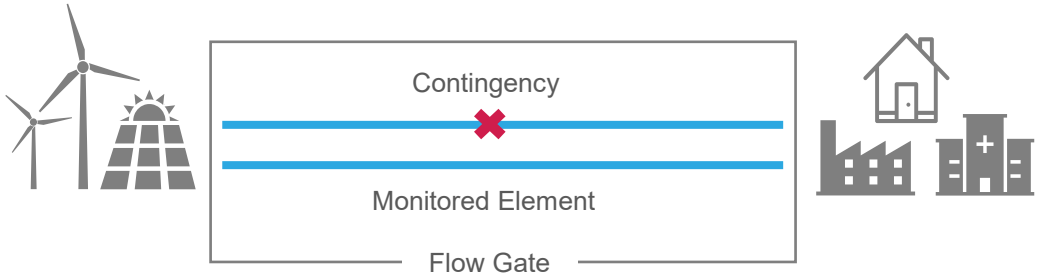
~ 72% had withdrawn from queues

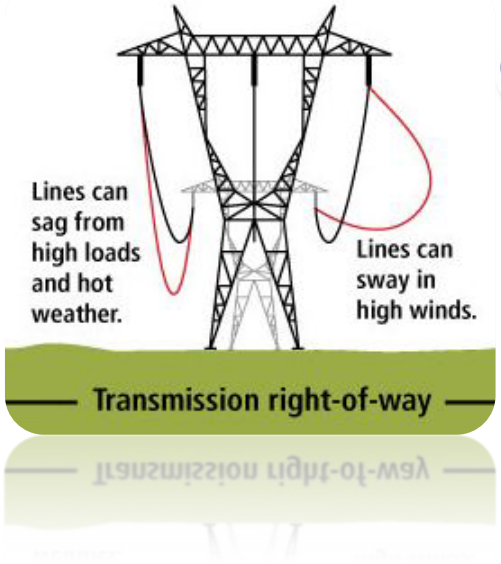
Rising interconnection costs and long queue delays for renewables may **impede clean energy goals** set at the federal and state level

GETs: Relieving Grid Congestion

Grid Enhancing Technologies (GETs) include, but are not limited to:

1. Power Flow Control (PFC) and transmission switching equipment
2. Storage technologies
3. Advanced line rating management
   - Ambient Adjusted Ratings (AAR)
   - Dynamic Line Ratings (DLR)
4. Advanced Conductors





Power Flow Control is a set of technologies that push or shift power away from overloaded lines and onto underutilized lines/corridors within the existing transmission network. Multiple power flow control solutions exist.

Dynamic Line Ratings (and Ambient Adjusted Ratings) Utilizes hardware and/or software used to appropriately update the calculated thermal limits of existing transmission lines based on real-time and forecasted weather conditions

Contingency - the loss of a transmission component

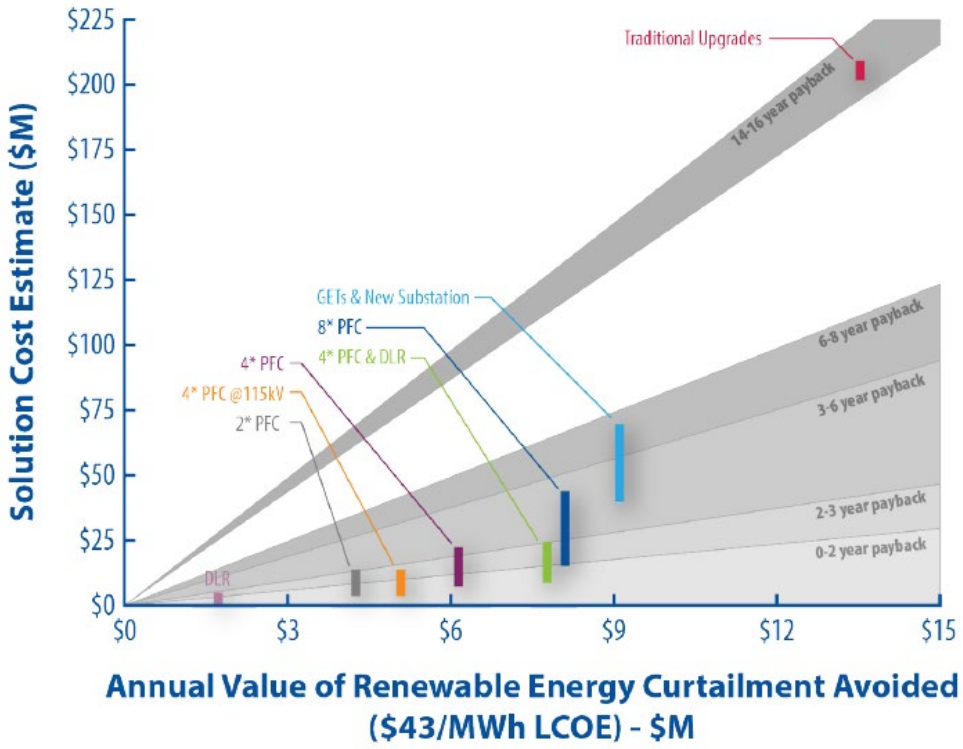
Monitored Element - the elements overloaded when a contingency happens

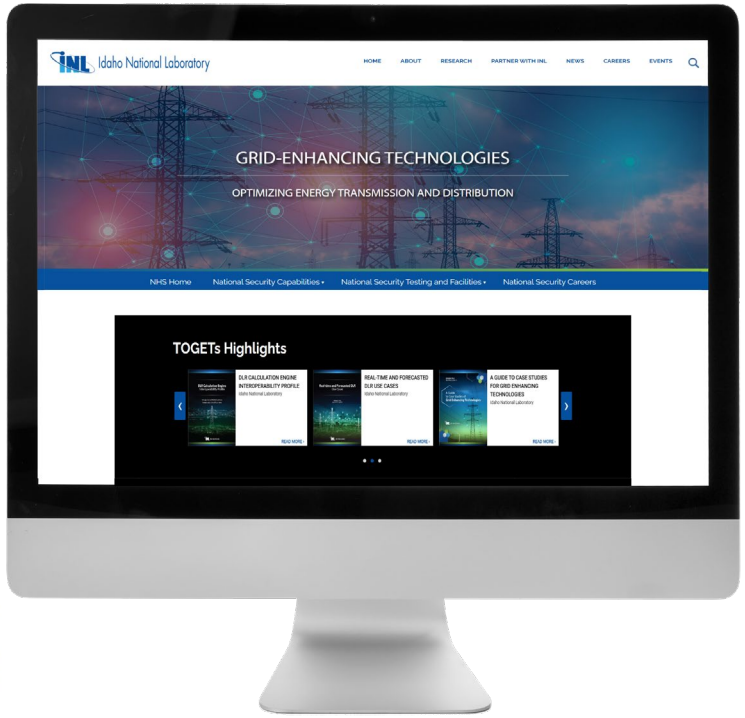
Flowgate – the contingency and monitored element pair that limit power transfer across the transmission system (from wind/solar to load in this example)

GETs definition from FERC Notice to Convene a Workshop on Grid-Enhancing Technologies: https://cms.ferc.gov/media/7198

GETs: Relieving Grid Congestion

Outlines of cost estimates for the various technology strategies considered relative to the annual value of energy curtailment avoided





https://www.energy.gov/sites/prod/files/2019/08/f66/Congressional_DLR_Report_June2019_final_508_0.pdf
https://www.energy.gov/sites/default/files/2022-04/Grid%20Enhancing%20Technologies%20-%20A%20Case%20Study%20on%20Ratepayer%20Impact%20-%20February%202022%20CLEAN%20as%20of%20032322.pdf

GETs website:
inl.gov/national-security/grid-enhancing-technologies/

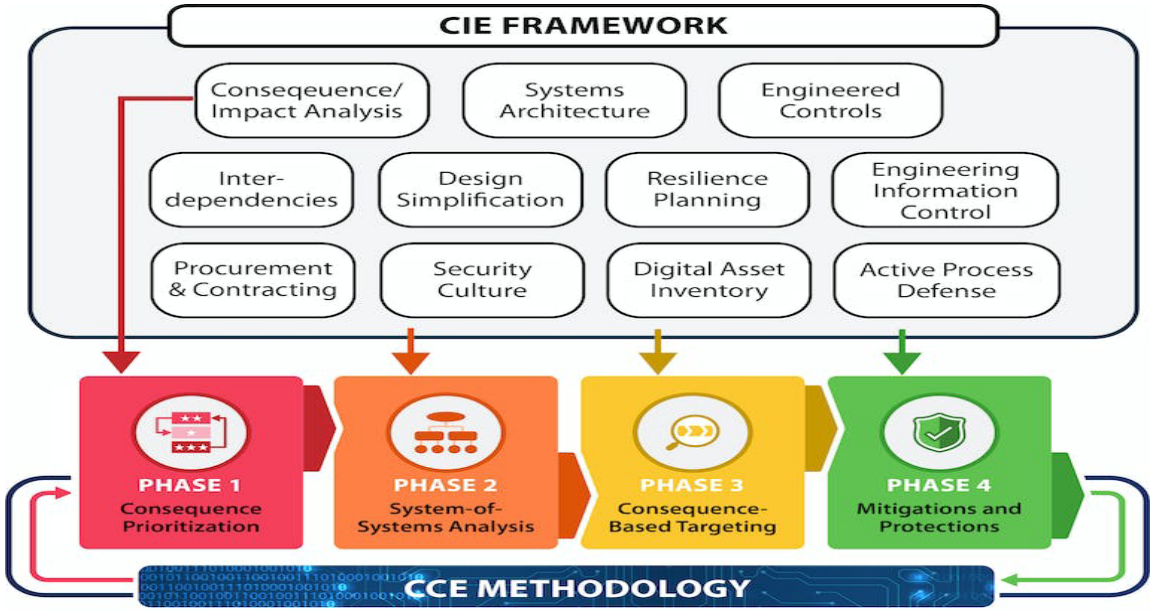
- Background
- Variety of products
  - Guide to Case Studies for GETs
  - Real-time and Forecasted DLR Use Cases
  - DLR Forecast Time Frames
  - Interoperability Profile
- Related Information

DLR website:
inl.gov/national-security/dynamic-line-rating/

- Last 10-15 years of DLR R&D
- Overview of DLR
- Technical Articles and Papers

Cybersecurity: Opportunities and Challenges

- To accelerate the deployment of clean energy solutions, we must ensure that energy systems are secure and resilient to disruption.
- Field sensing devices, communication links, third party hosting services, controllers, power electronics, and other elements of these new systems are all potential threat vectors available to malicious actors
- Users and stakeholders for consumer-facing energy systems need a way to learn about specific security vulnerabilities in products serving their energy needs, like solar inverters or smart meters



CyTRICS

- Tests OT vulnerabilities, shares information with manufacturers to develop mitigations, and alerts industry stakeholders using deployed impacted components

CyOTE

- Aims to enhance energy sector threat detection of anomalous behavior potentially indicating malicious cyber activity in OT networks

CCE

- The INL Patented Consequence-driven Cyber-informed Engineering (CCE) effort provides both private and public organizations with the steps required to examine their own environments for high-impact events/risks

CIE

- The Cyber-Informed Engineering (CIE) framework and body of knowledge drives the inclusion of cyber security as a foundational element of risk management for engineering of functions aided by digital technology.

Idaho National Laboratory

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