Integrated Grid Planning Symposium
State of IGP Technology

16 November 2017

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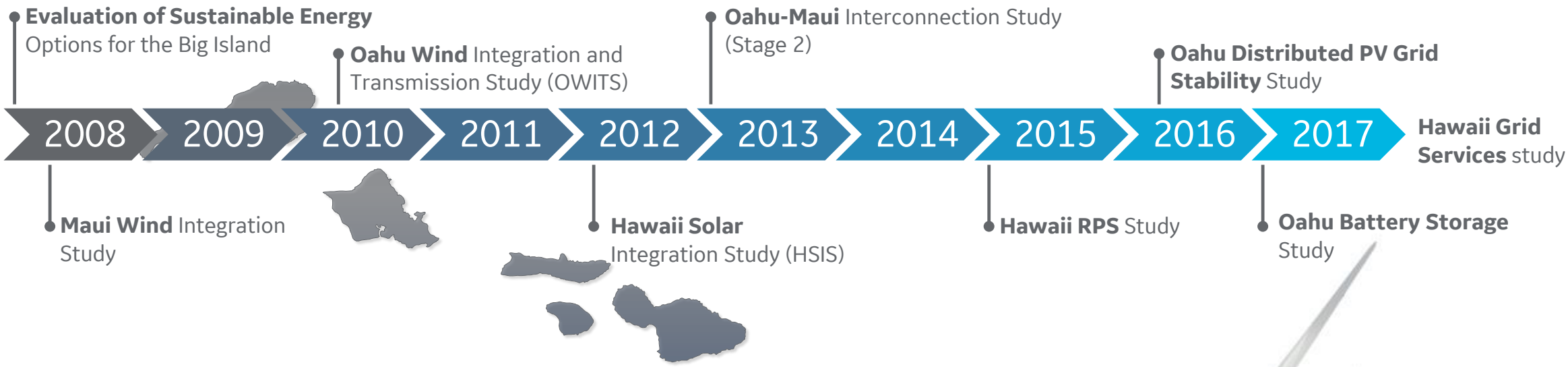
GE's Hawaii Grid Planning Experience

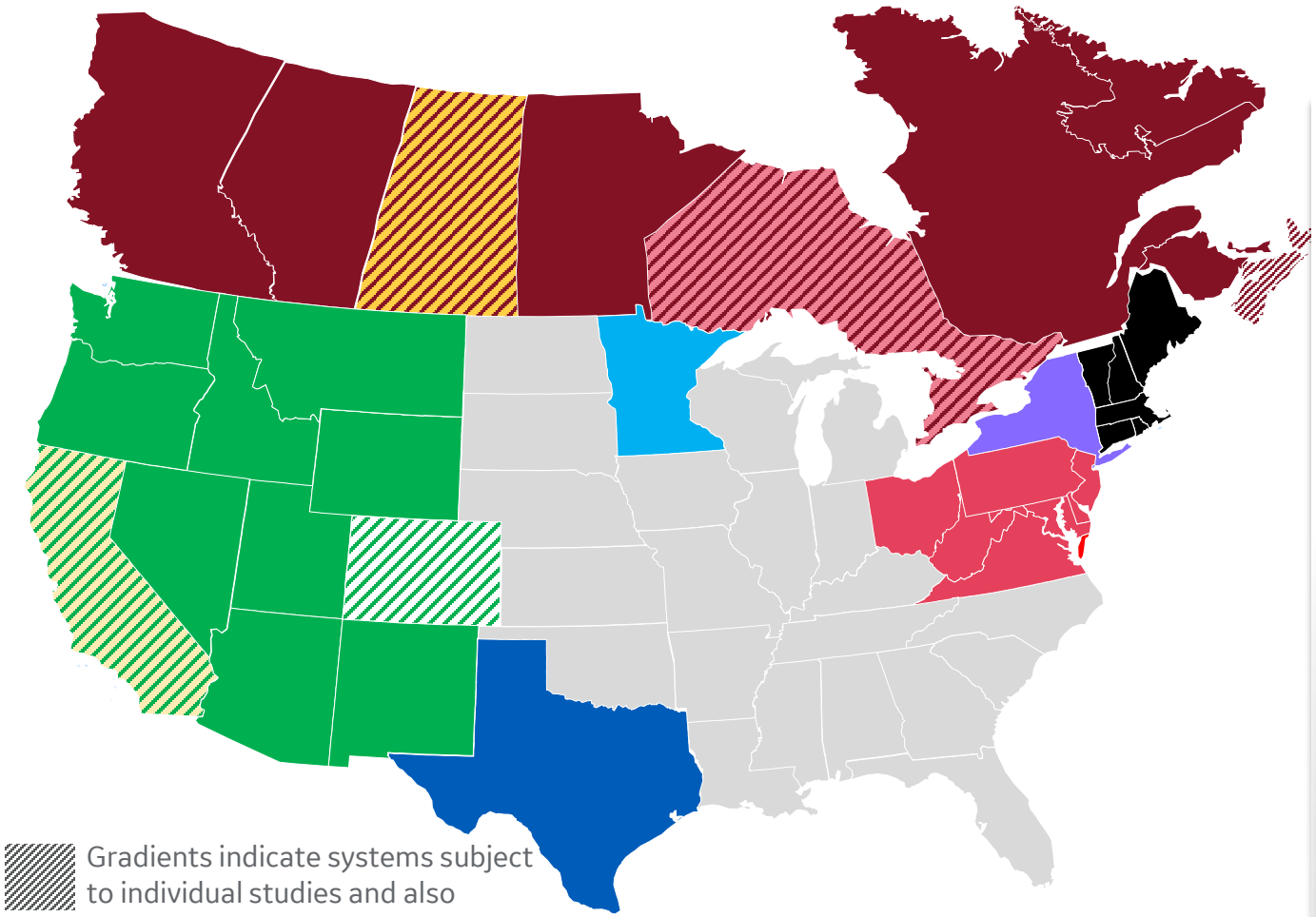


For more information and recent reports:
http://www.hnei.hawaii.edu/projects#GI

Special thanks to:

HNEI
Hawai'i Natural Energy Institute
School of Ocean and Earth Science and Technology
University of Hawai'i at Mānoa

Sharing Best Practices from across the Industry



Gradients indicate systems subject to individual studies and also included in larger regional studies

2004 New York
3 GW Wind
10% Peak Load
4% Energy

2005 Ontario
15 GW Wind
50% Peak Load
30% Energy

2006 California
13 GW Wind
3 GW Solar
26% Peak Load
15% Energy

2007 Texas
15 GW Wind
25% Peak Load
17% Energy

2009 Western U.S.
72 GW Wind
15 GW Solar
50% Peak Load
27% Energy

2010 New England
12 GW Wind
39% Peak Load
24% Energy

2012 Nova Scotia
~1500MW Wind
40% Energy

2013 PJM
96GW Wind
22GW Solar
30% Energy

2014 Minnesota
8 GW Wind
4.5 GW Solar
50% Energy

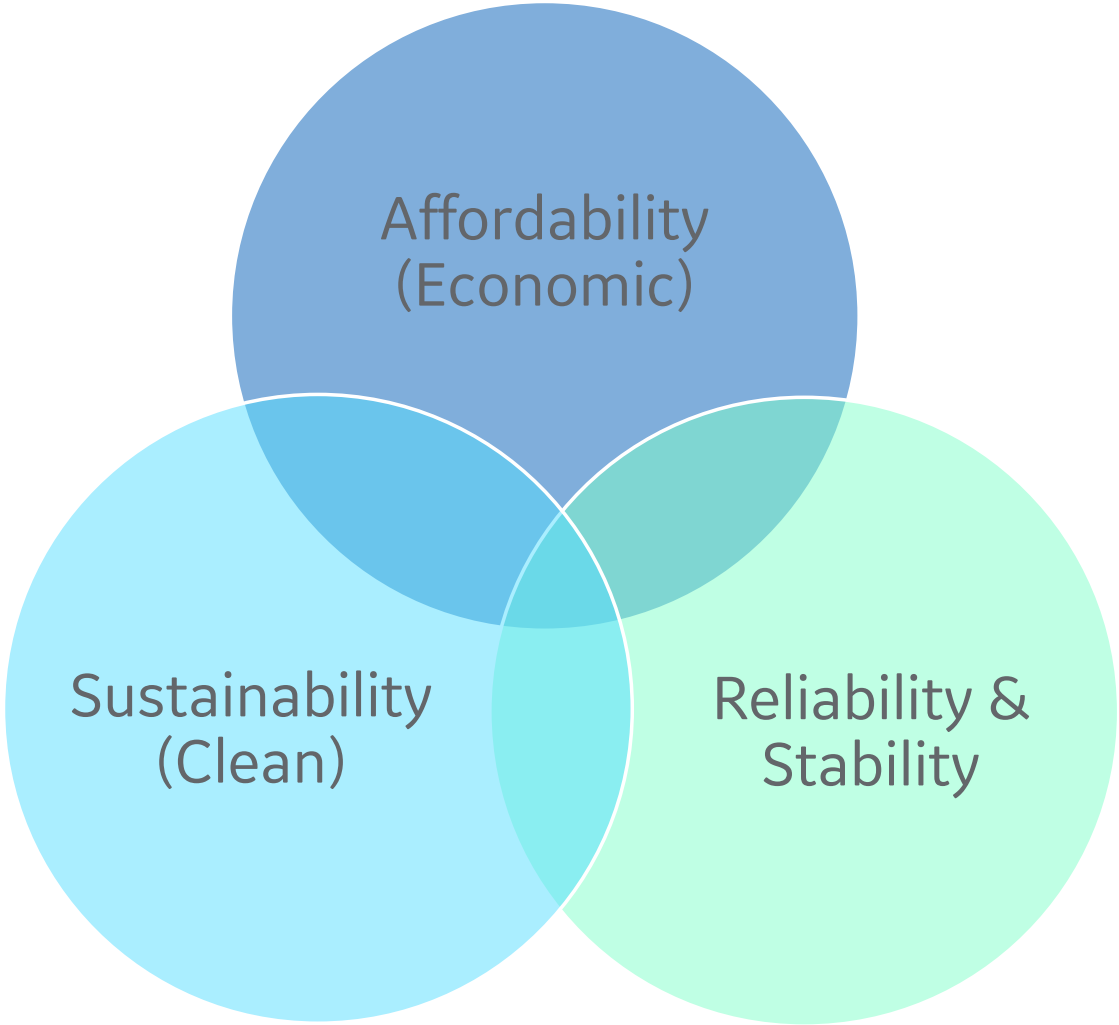
2016 Pan-Canadian
~72GW Wind
30% Energy

Underway
Saskatchewan
Colorado Springs

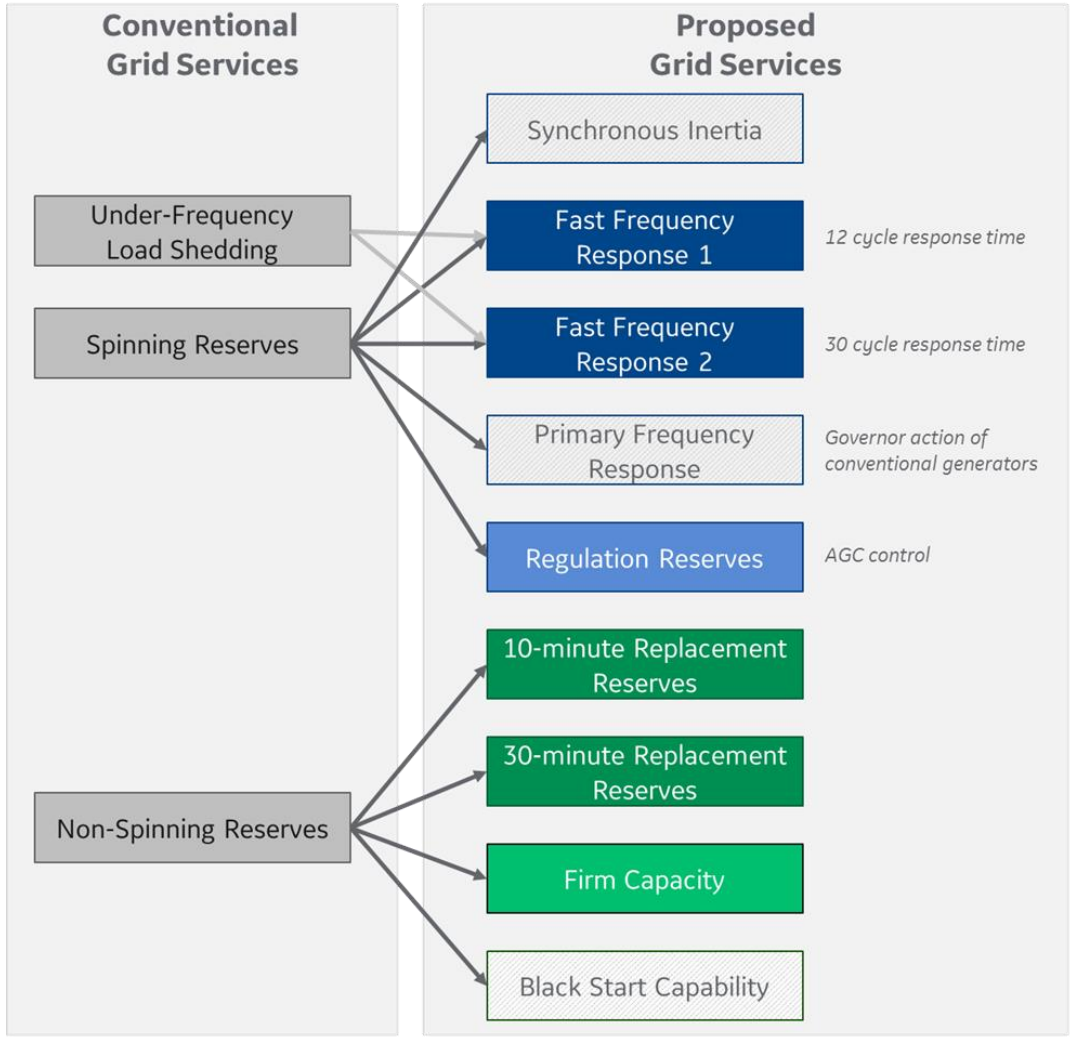
Three Pillars of Power System Planning & Operations

Don't take reliability and stability for granted!

- Customers want their electricity to be affordable, clean, and reliable … all are important
- Part of a comprehensive analysis for power system planning
- Responds to emergency (contingency) events, not normal operations
- Important at different time scales of system operation; seconds to minutes



Grid Services are Evolving Across the Industry



Source: Adapted from ERCOT, Cost-Benefit Analysis of ERCOT's Future Ancillary Services (FAS) Proposal

"Grid Services" also known as *Ancillary Services* or *Essential Reliability Services*

General trend away from "ancillary" … now a primary rationale for system operator decisions (commitment and dispatch of generators),

Especially relevant for Hawaii and other island systems

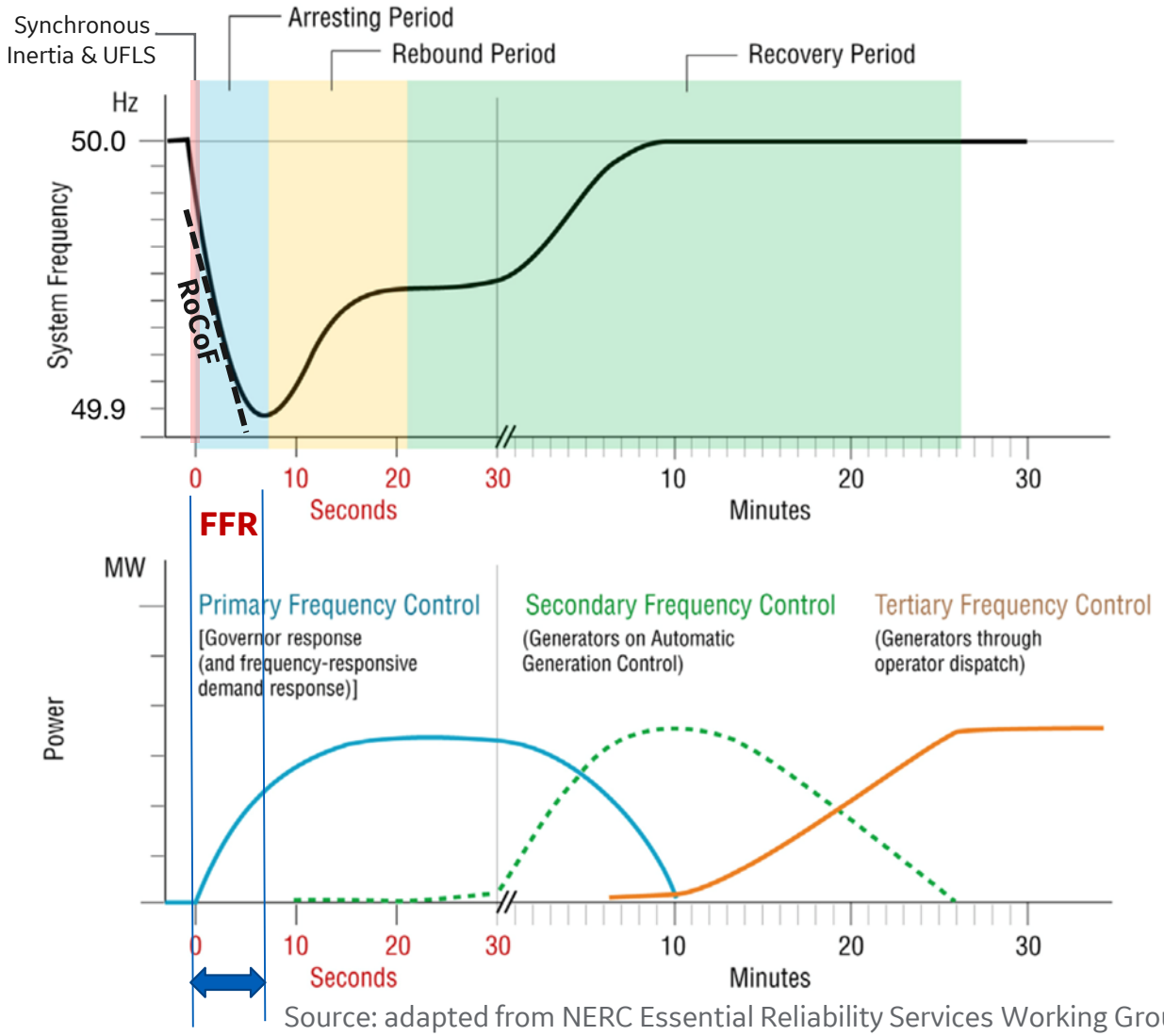
Other grid services, not evaluated in this analysis:

- Short Circuit Strength and/or Voltage Support
- Synchronous Inertia
- Primary Frequency Response
- Ramping Reserves
- Black Start Capability

Maintaining grid stability requires actions within ~~seconds~~ cycles

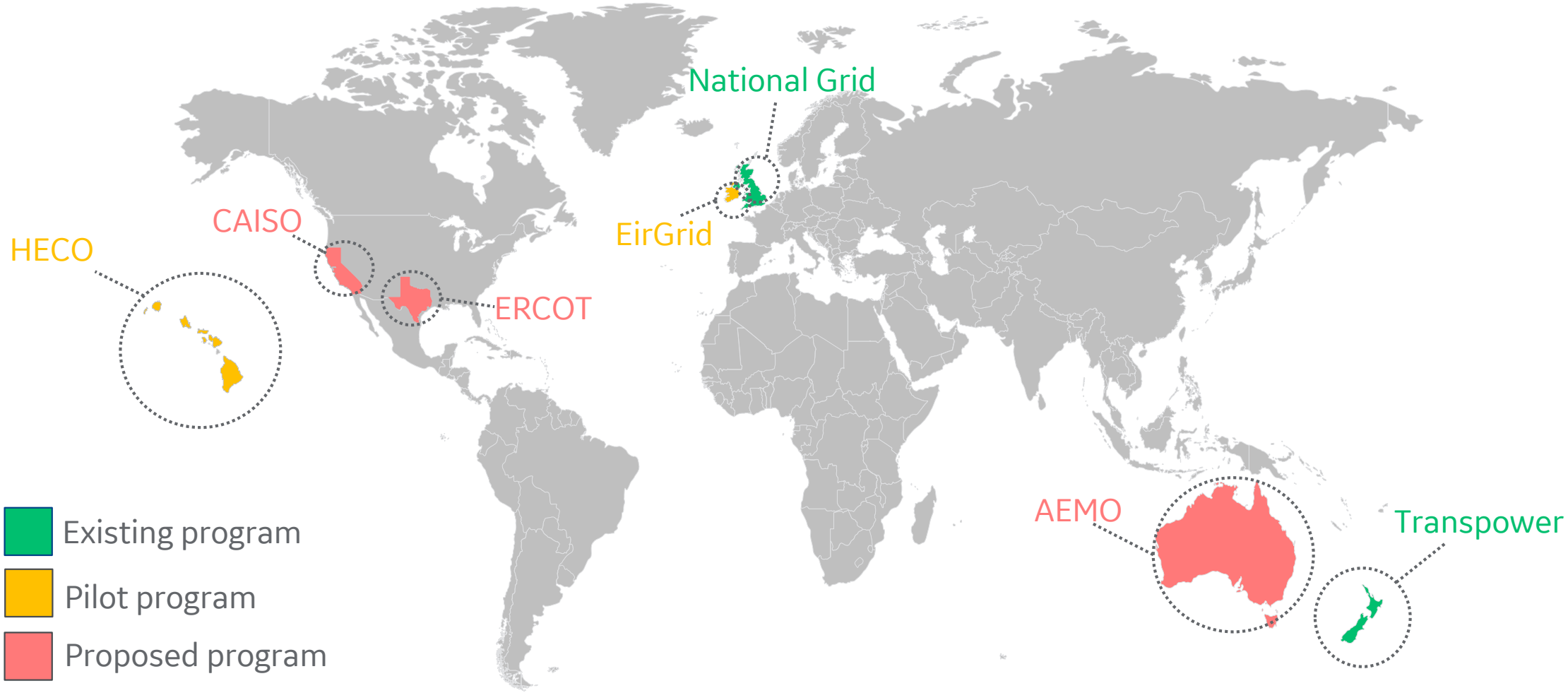
- Grid must be prepared for and respond to emergency (contingency) events
- Important at different time scales of system operation; sub-seconds to minutes
- During a contingency, system frequency will change quickly (high RoCoF*)
- Conventional response is from system inertia (kinetic energy in synchronous generator)
- As renewables increase, system inertia decreases, leading to faster changes

*RoCoF = rate of change of frequency = df/dt



Source: adapted from NERC Essential Reliability Services Working Group

Where are FFR programs taking shape?



Modeling Tools for all Timescales of Power Systems

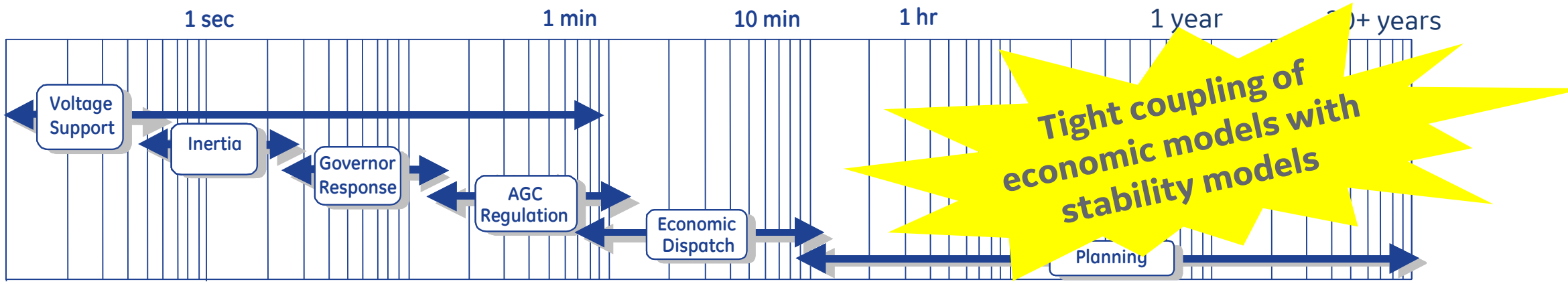
No one tool does it all…

GE PSLF Grid Simulations

- Voltage & stability performance
- Frequency response
- Contingency analysis

GE MAPS or PLEXOS Production Cost Simulations

- Sub-hourly chronological dispatch model
- System operations and economics with increasing levels of W&S integration



STATISTICAL Variability Analysis

- Characterize wind and solar variability
- 2 sec data to 60 min
- Develop operating reserve profiles

GE MARS Reliability LOLE Simulations

- System reliability model
- Calculates loss of load expectation (LOLE), resource adequacy, and capacity value of wind and solar

Next Steps & Ongoing Analysis

- ❑ How should FFR be designed & calibrated?
- ❑ What is the capacity value of storage and demand response?
- ❑ What is the value of resource diversity?
- ❑ What mitigations can reduce curtailment and save money?

What do you think we need to evaluate?

Thank You!

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