# 100% Renewables Initiative

Debra Lew
GE Energy Consulting

**October 2, 2018**

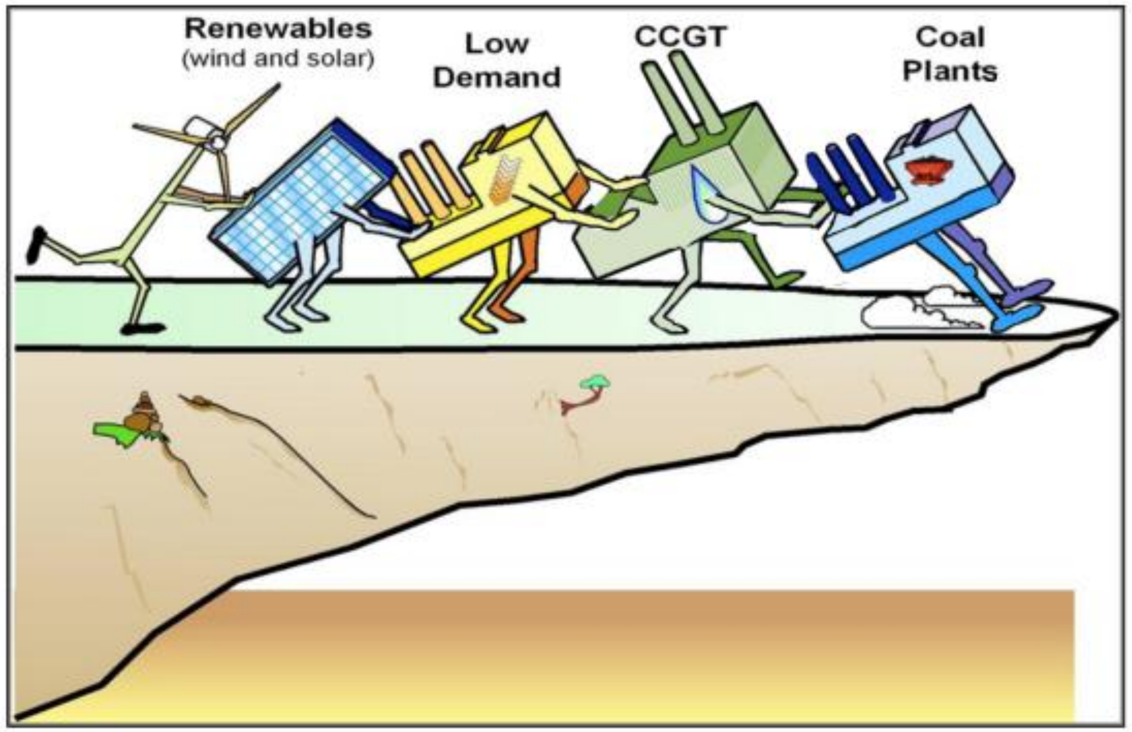
# This year, ESIG started focusing on ***100% Renewables***

- Problem statement: There's a lot of interest in 100% renewables, but not a lot of thought as to what that means for *all aspects of power system planning and operations* and on a large scale (not just a muni)
- ESIG Working groups considering how their efforts can help investigate different aspects of 100%
- ESIG is collaborating with GE, EPRI, NREL, GridLab to bring more resources to bear on this topic

# This study attempts to answer:

- What’s the best we can do today in renewable energy penetration levels? How far can we get with what we know today?
- What are the fundamentals that may change under 100% renewables scenarios? What are the paradigm shifts?
- Does 100% renewables make sense? What are the benefits? What are the costs? What are the enabling technologies?
- What is the path from here to there?

# There are many questions that need to be addressed

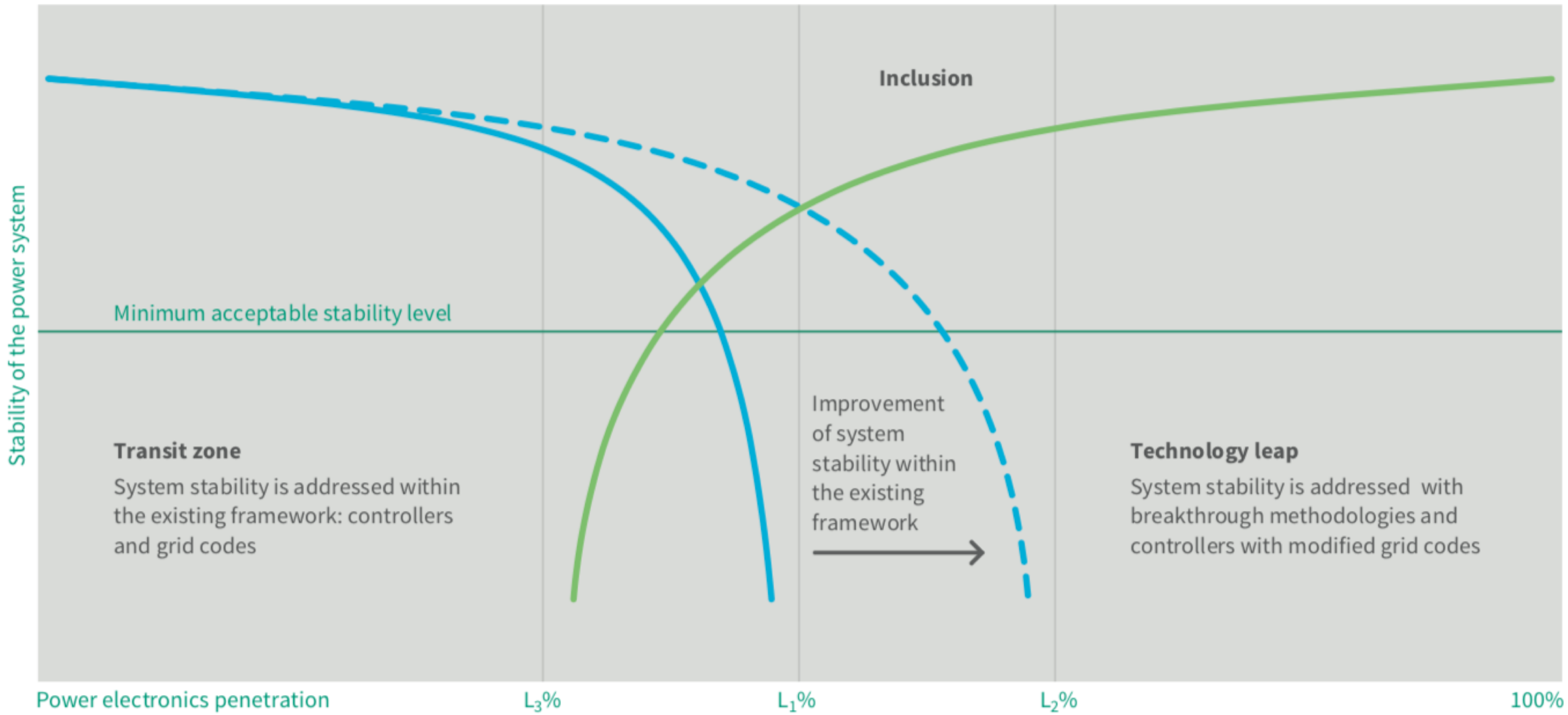



- How do the energy, capacity, ancillary services markets evolve?
- What's the role of gas versus storage?
- What's the role of demand flexibility versus storage?
- What are the requirements for grid-forming converters?
- What is the role of inertia in the future?
- What are the requirements for grid architecture?
- How fast can these changes occur? What needs to happen for these changes to occur?

***Where are the cliffs?***

Source: Leo Norton adapted from Corina Morhlen

# You can't get there from here without a paradigm shift

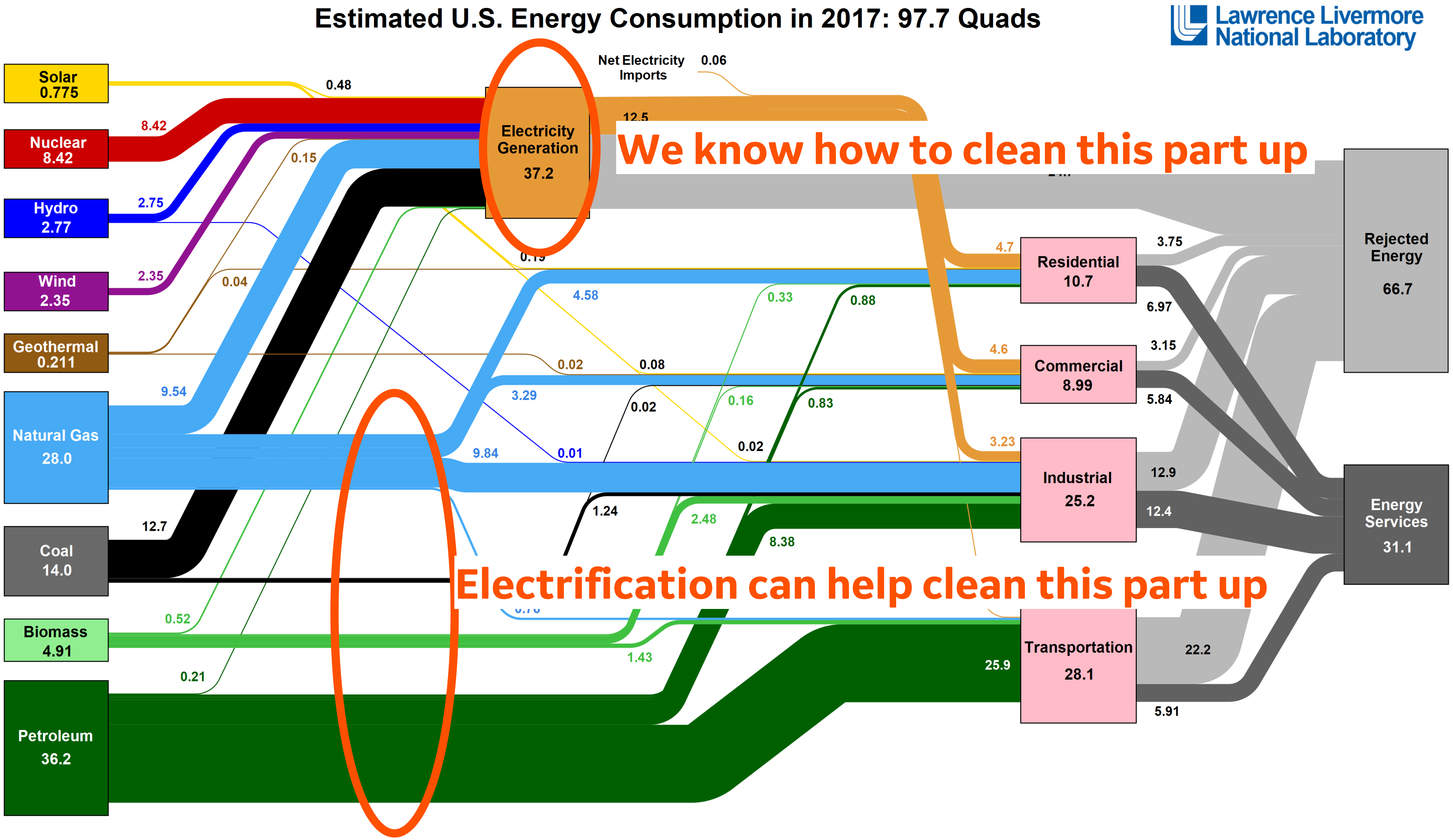



MIGRATE, 2016

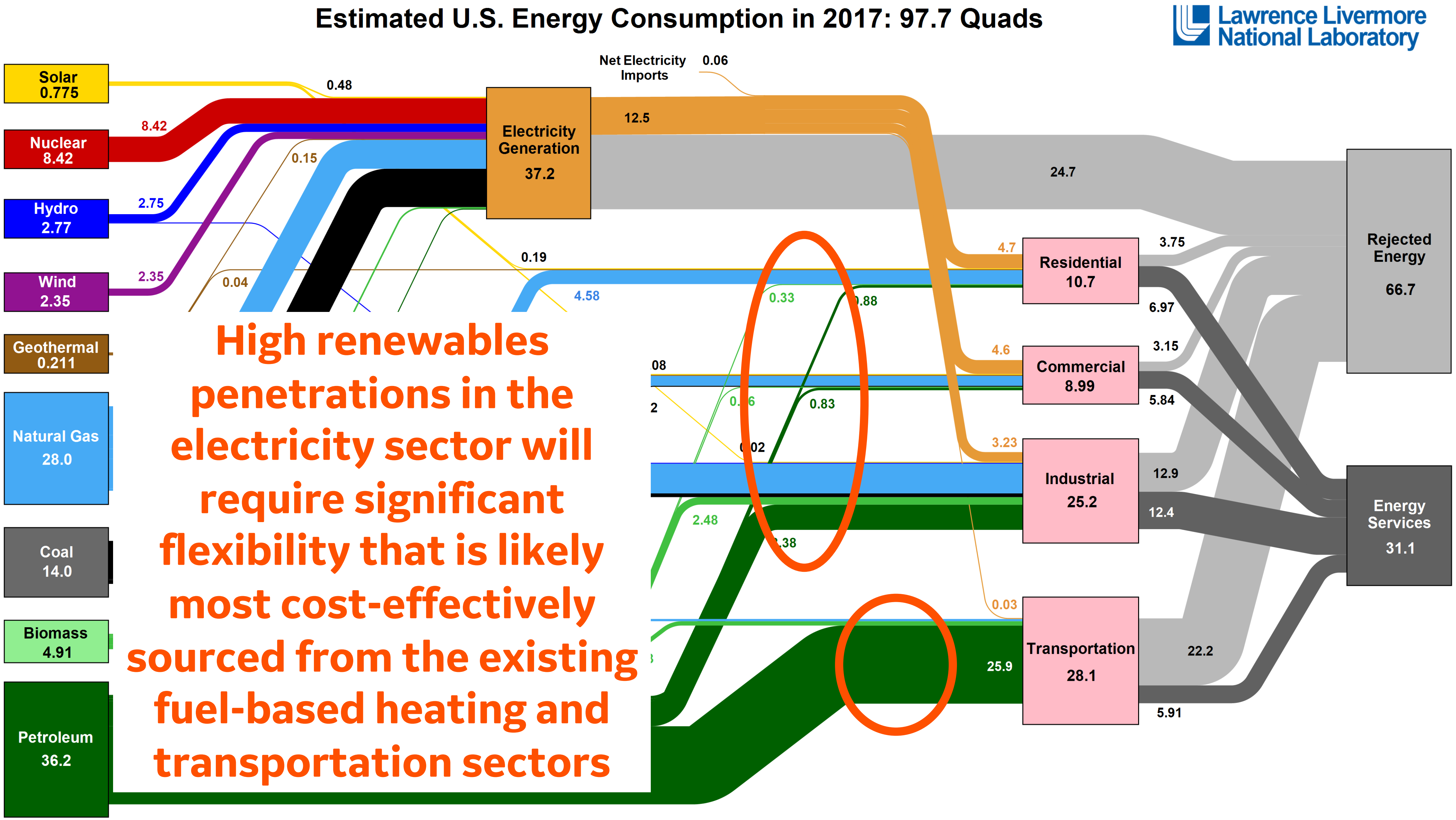
**Today we are on the blue line and working towards the dashed blue curve.**

**We don't know what the green curve looks like or how to get there.**

# And a paradigm shift in integrating other energy sectors



# And a paradigm shift in integrating other energy sectors

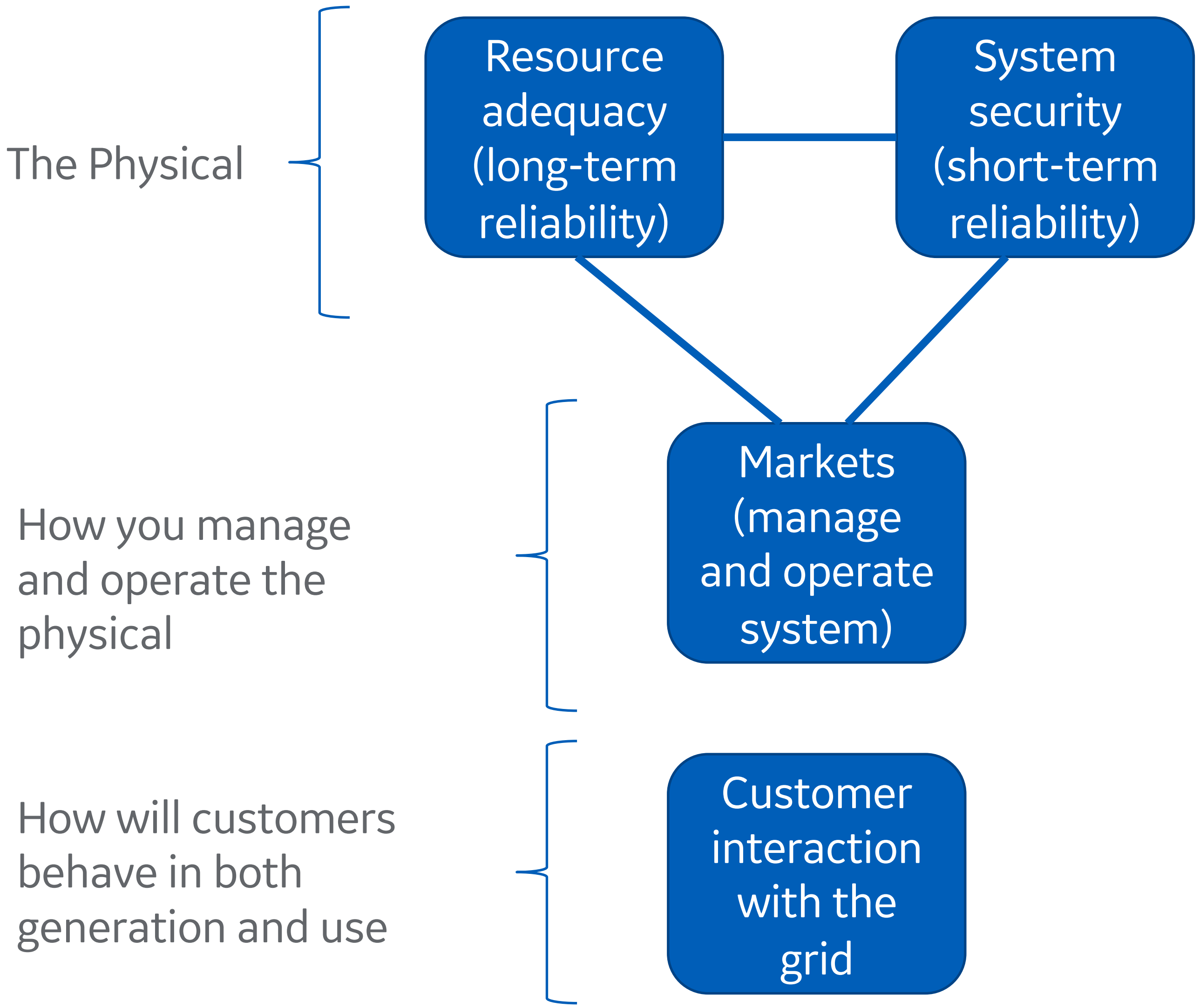



**High renewables penetrations in the electricity sector will require significant flexibility that is likely most cost-effectively sourced from the existing fuel-based heating and transportation sectors**

# Potential power system fundamentals that could change (not exhaustive list!)

- Frequency as control variable
- Obligation to serve (Reliability at customer level)
- Active, possibly real-time participation of customers, in both directions
- AC vs DC
- Resilience
- Re-regulation

# Focus areas and examples of issues to investigate




**System Security: Stability with high penetrations of inverter-based resources**

- Inertia
- Frequency
- Protection

**Resource adequacy: What is the resource mix and how does it balance load?**

- Capacity expansion
- System balancing
- Loss of load expectation (1 day in 10 years)
- Power to X
- Energy systems integration

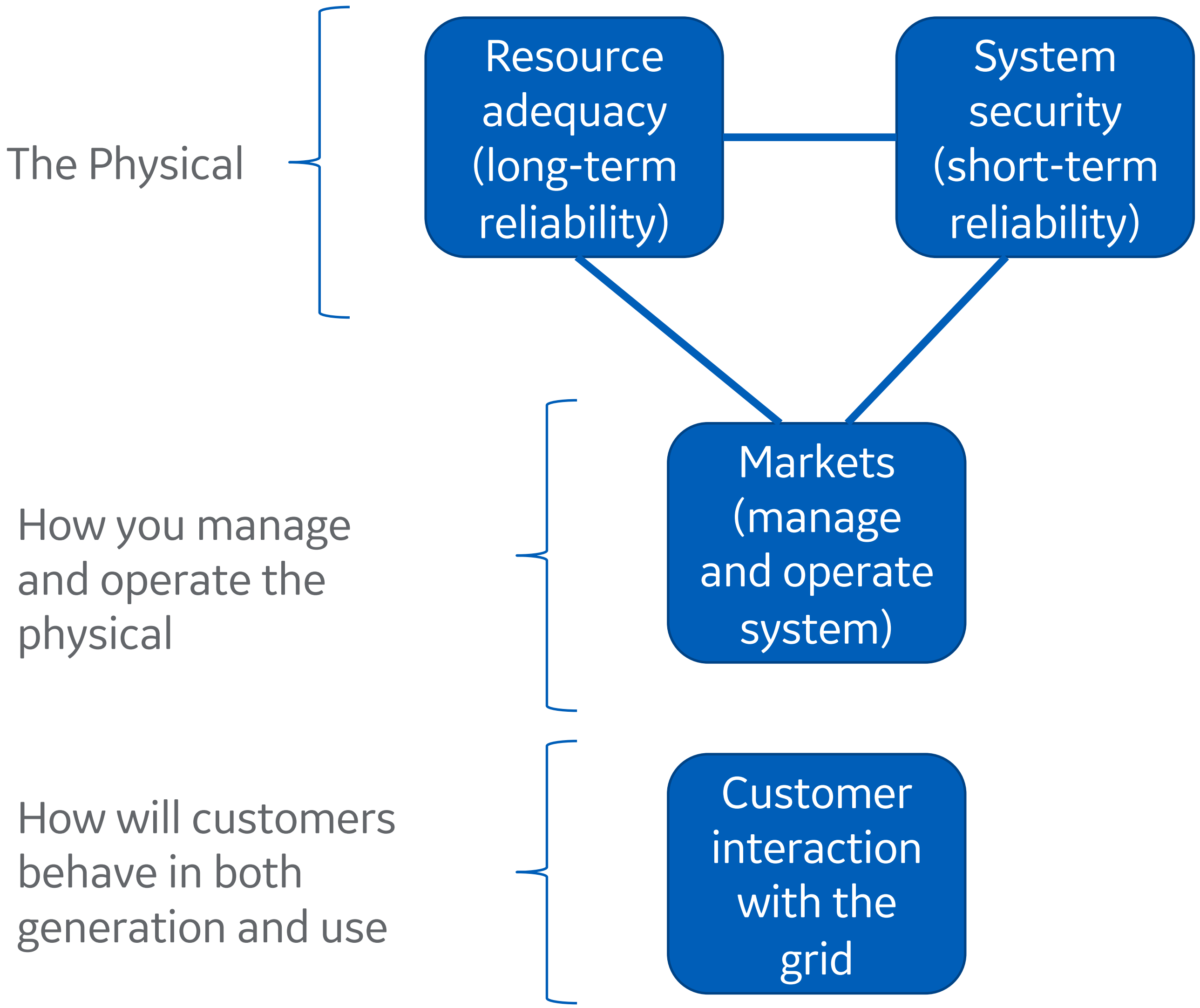
**Markets**

- Capacity/energy/ancillary services
- Re-regulation?

**Customer behavior**

- DERs
- Flexibility from loads
- Transactive/grid architecture

# Focus areas and examples of issues to investigate




**System Security: Stability with high penetrations of inverter-base**

- Inertia
- Frequency
- Protection

**Resource adequacy: What is t e resource mix and how does it balance loa ?**

- Capacity expansion
- System balancing
- Loss of load expectat on (1 day in 10 years)
- Power to X
- Energy systems integrat

**Markets**

- Capacity/energy/ancillary se es
- Re-regulation?

**Customer behavior**

- DERs
- Flexibility from loads
- Transactive/grid architecture

Nearly all 100% studies focus only on this

And maybe some level of this

# The end goal is carbon reductions

- We're really talking about deep decarbonization.
- But we're really talking about *increased electrification* and *very high use of zero carbon resources* to generate that electricity.
- 100% renewables may not actually be the goal but studying it will help us understand how to get to 80 or 90% renewables.
- This is not advocacy. This is a scientific study.

# What does 100% mean?

# The definition depends on who (and where) you are

## Size

House
Business
City
Balancing Authority
Entire interconnection

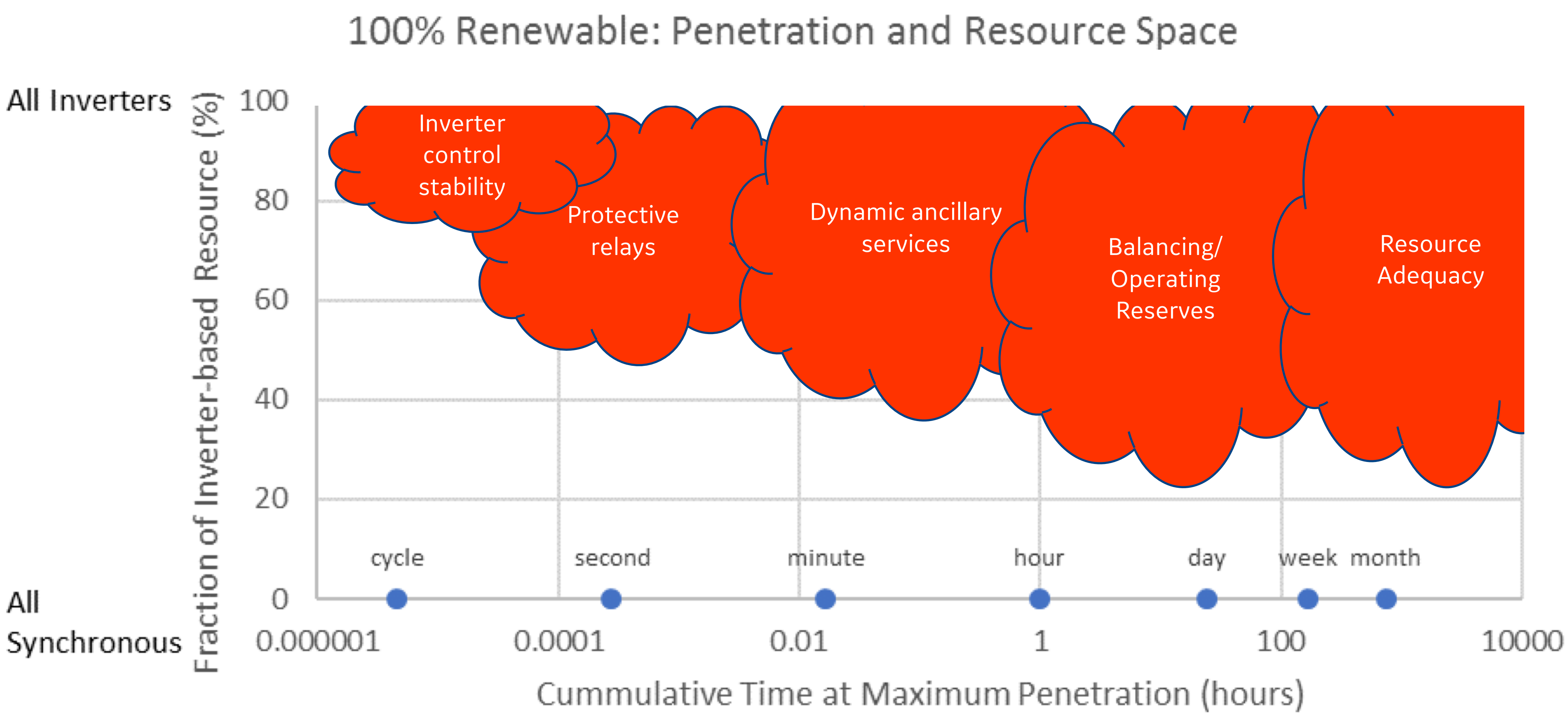
## Time

- 1 second
- 5 minute
- 1 hour
- Day
- Year

## Penetration of inverter-based resources

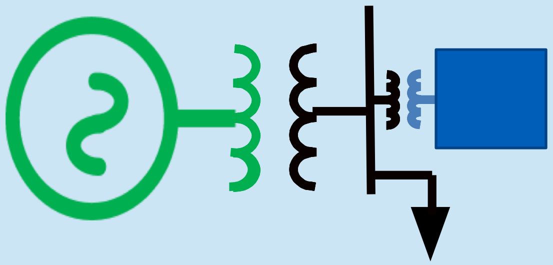
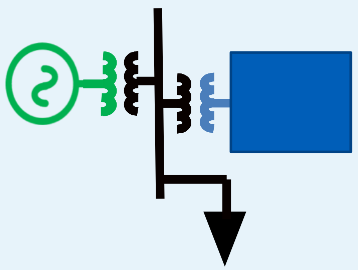
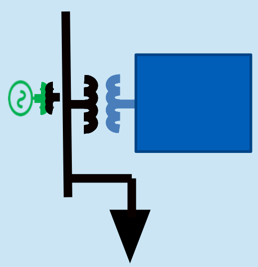
- 100% synchronous generation
- 50% synchronous
- 0% synchronous

# Pinch Points based on inverter penetration

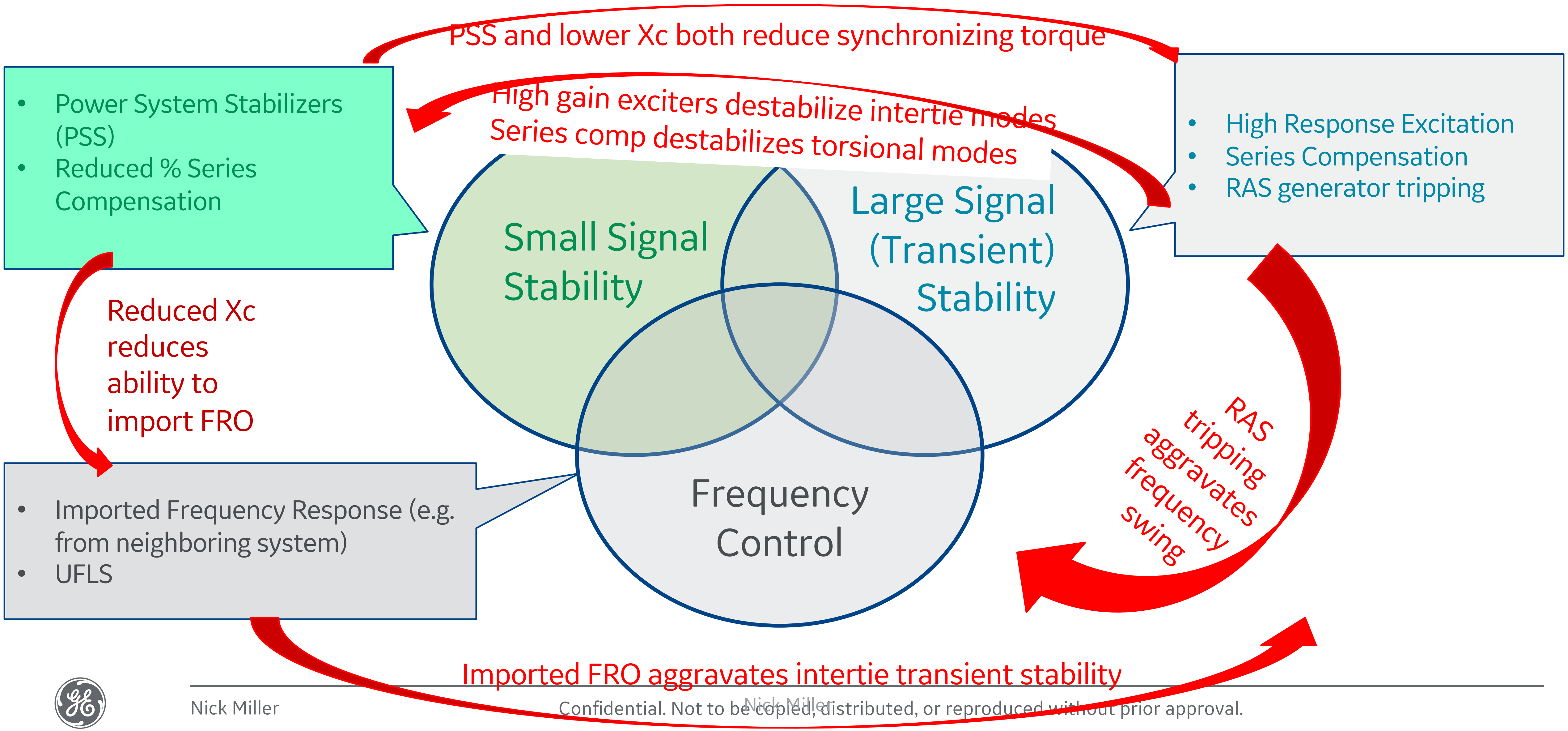


# Reliability Working Group

# Inverter Based Source -Fast Controls: High % Grid Following

| | Small Signal | Large Signal |
|---|---|---|
|  | Typically all regulators with stable operation | Fast recovery after faults<br>Synchronization transients are short |
|  | Typically all regulators with stable operation | Longer synchronization transients on fault recovery<br>Potential limit cycles with LVRT logic operation<br>Voltage collapse on recovery |
|  | Synchronization oscillations or divergence possible<br>Current control loops oscillations due to ineffective de-coupling  or other effects of grid impedance<br>Voltage regulator loop instabilities | All of the above and the small signal issues |

# Some interactions and trade-offs today






Nick Miller

# Operations and Markets Working Group

# Operations and Markets Working Group

## 100% renewables

- Lots of discussion on definition and scope of effort - 100% inst. in regions was popular
- Price formation and demand being more active in pricing are areas of interest
- More than existing organized markets, and think about other means, such as bilateral, long term procurement, etc.
- Operations aspects are also important – balancing, reserves, etc.
- Value in describing the issues and some recent experiences
- Market and ops should be split up in this effort

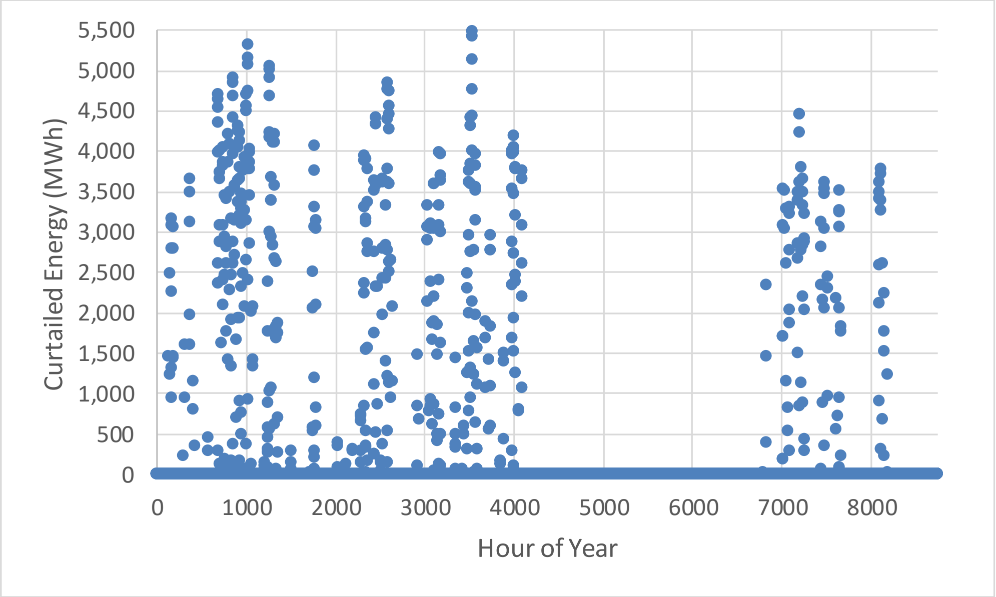
## Discussion on recent experiences

- Informal discussion to identify issues and solutions
- XM (Colombia system operator) on what they are focusing on – forecasting, flexibility, grid code and DER
- Modeling tools and methods for high VG penetration – advanced production cost modeling tools
  PSH modeling
  Gas/electric
- Topology control study in SPP showing benefits of switching out lines to reduce congestion with high wind penetration
- Storage discussion –recent experience, FERC Order 841

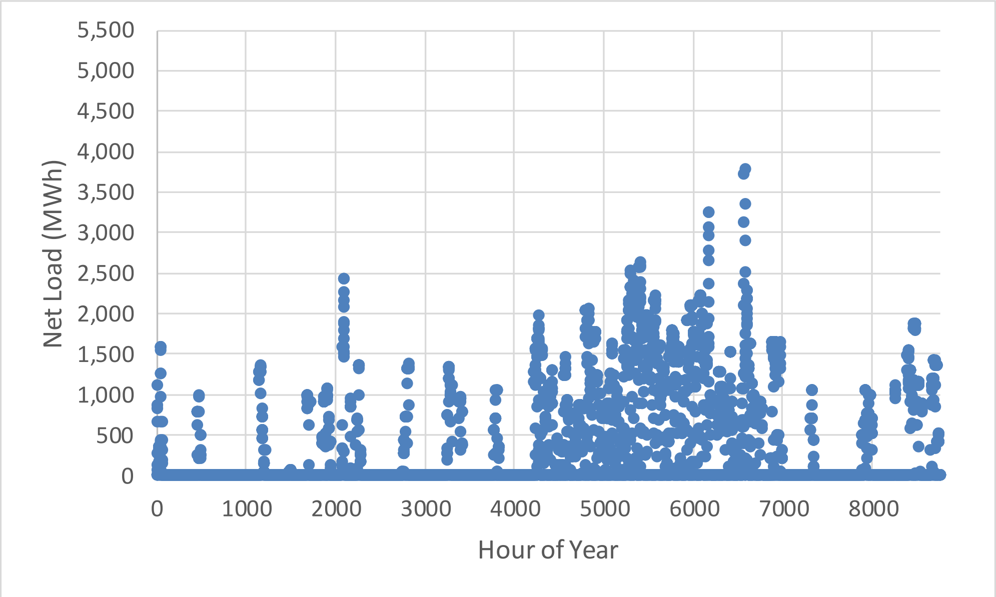
# Planning Working Group

# Seasonal Mismatch

- If the goal is to obtain 100% of electricity from renewables on an annual basis, then inverter based challenges are the least of our worries.
- The seasonal mismatch problem will result in massive curtailments for large parts of the year, and substantial energy deficiencies at other times of year.
- Resource adequacy just got a whole lot harder



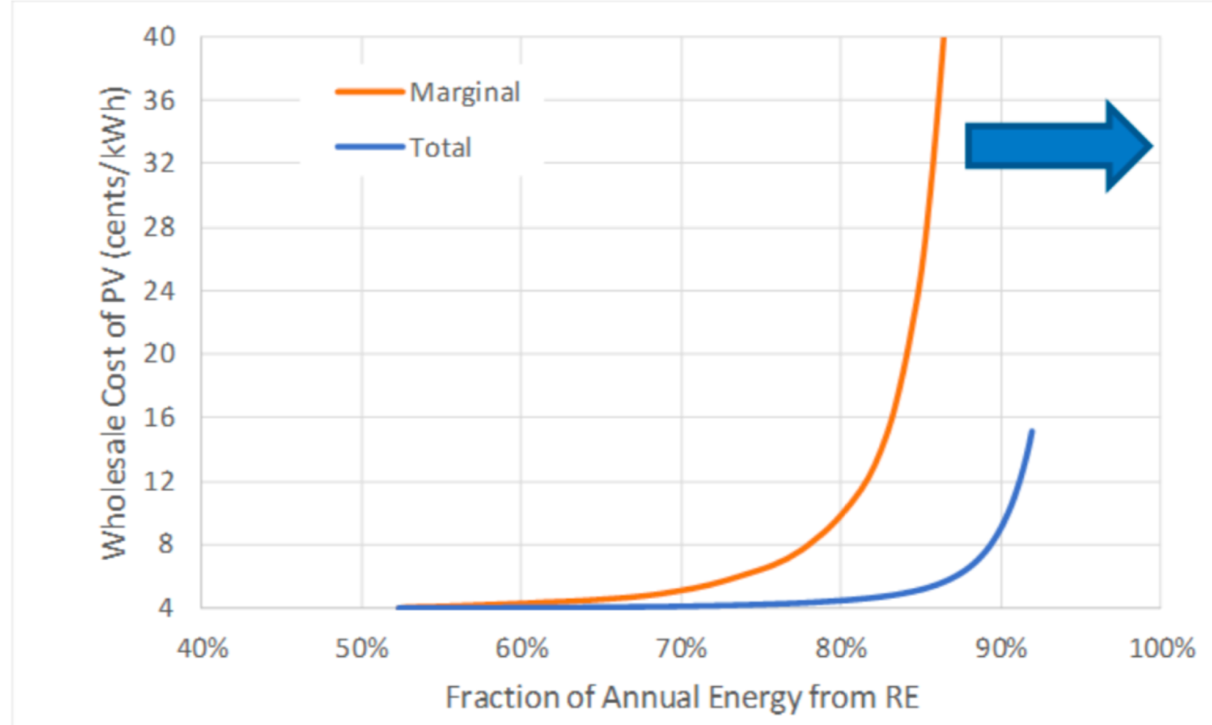

Hours of Surplus Energy

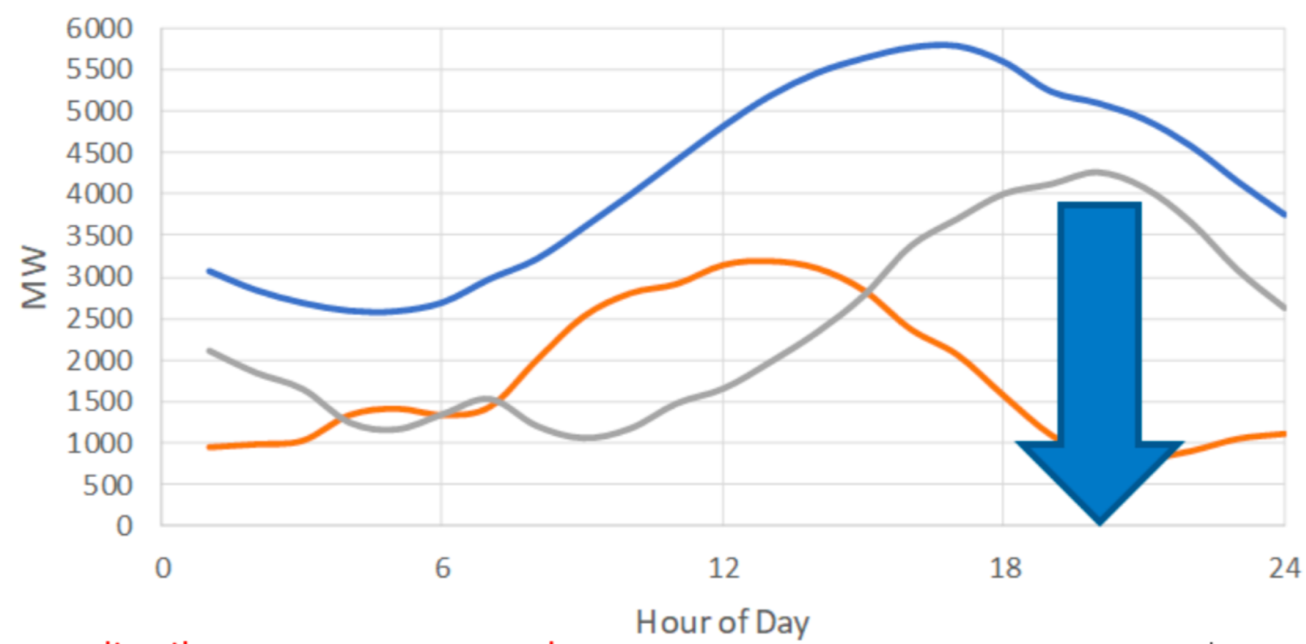



Hours of Energy Deficiency

# Finding Solutions

- We need to find a mix of resources that shift the cost curve
- And find a mix of resources that will meet the demand for reliable energy during all hours of the year



# DER Working Group

# Load flexibility and DERs become essential

**What might the challenges look like?**

- Consider a region with extremely high levels of variable renewables (wind, solar, hydro, biomass)
- Increased electrification -> increased load that is more variable and less predictable
- DERs and community choice aggregators remove load from load-serving entities. Do load-serving entities still need to plan for that load?
- Climate change impacts on load and variable renewables
- Resource adequacy risk may become unwieldy and some risk may need to be transferred to customers.

**Different levels of 'reliability'**

- Interruptibility: Today, customers opt-in to demand response. Tomorrow, DR may be the default and customers may need to opt-in (and pay more) for "as much power as you want, whenever you want"
- Demand: Today, customers essentially use as much power as they want. Tomorrow, they may need to pay more to charge their EV, heat their hot tub and run their A/C simultaneously.
- Pricing: Tomorrow's time-of-use rates may have a far wider spread, or customers may be exposed to increasingly real-time prices. (What kinds of price signals do we need to change behavior?)

# Research and Education Working Group