NREL Transforming ENERGY

The Last 10%

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ESIG Fall Technical Workshop

Challenges of Increasing VRE: a few details

Resource Availability
- Renewable resources local and global
- Resource uncertainty and future changes
- Raw material resources (rare earth materials, etc.)

Supply/Demand Balance
- Resource Adequacy
- Declining Value/Increasing Curtailment

Variability and Uncertainty of Generation
- Operating Reserves
- Unit Commitment and Dispatch

Grid Reliability
- Cyber and Physical Threats

Grid Stability
- Transient and Dynamic Stability
- Frequency stability
- Voltage stability

Other Grid Considerations
- Protection Considerations
  - Short-circuit strength
- Blackstart capability

Techno-Economic

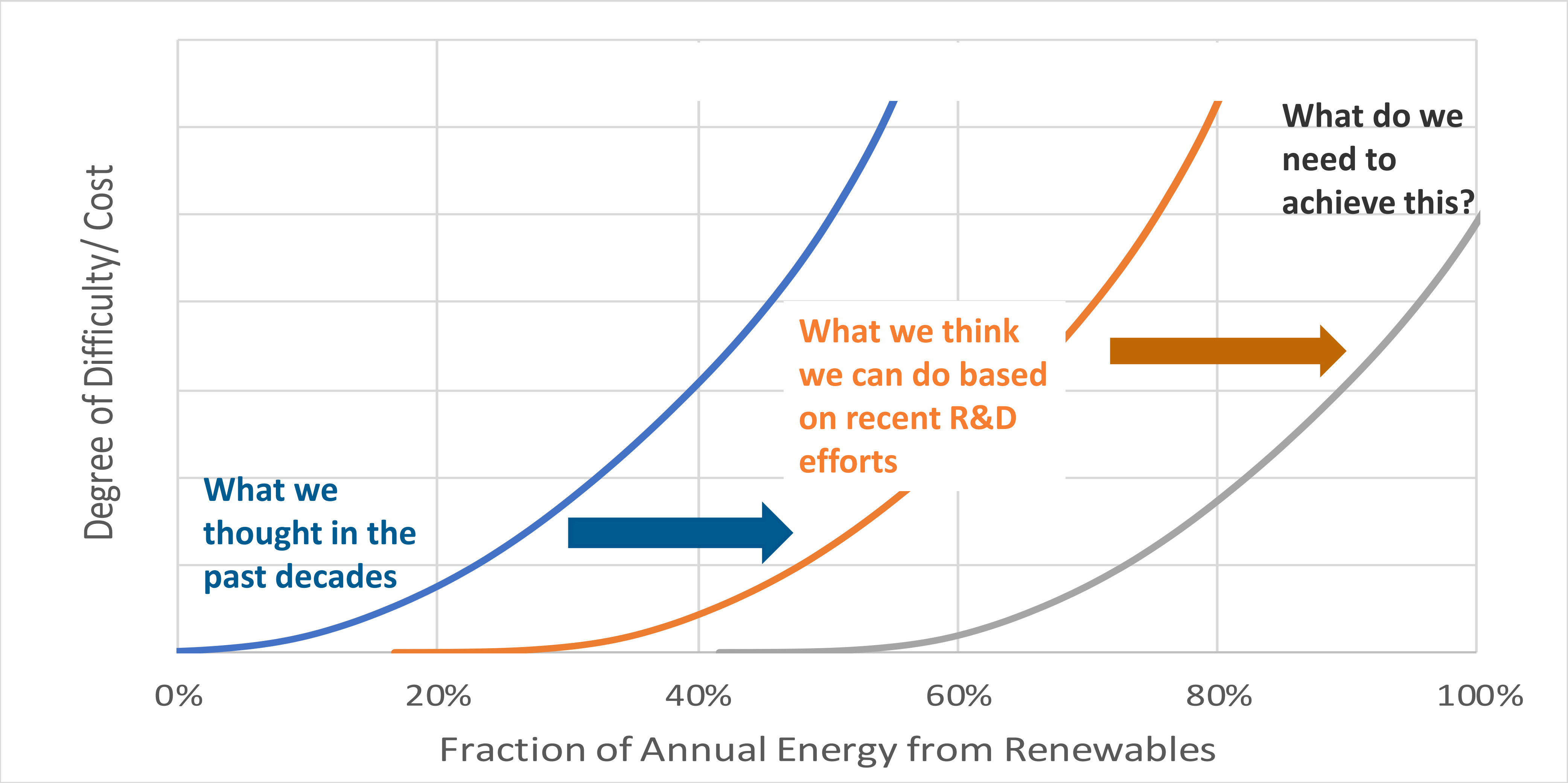
Engineering

Two big challenges:

1. The economic challenge: Addressing seasonal variability and other challenges of economic supply/demand balance
2. The engineering challenge: Achieving stable, reliable grids based largely on inverter based resources (IBR)

Both challenges are really both economic and technical…..

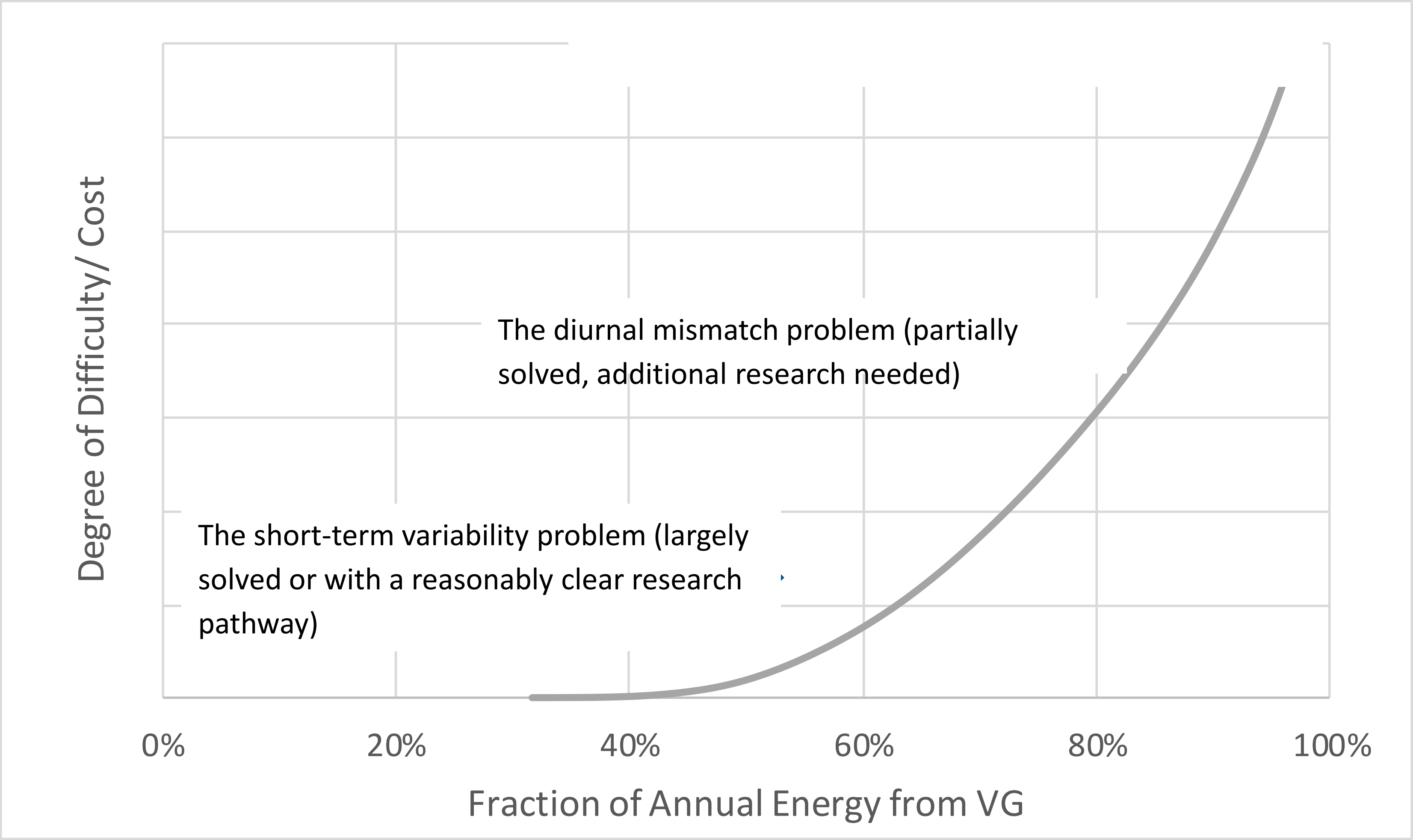
One Framework for Thinking About Achieving Increasing RE Penetration



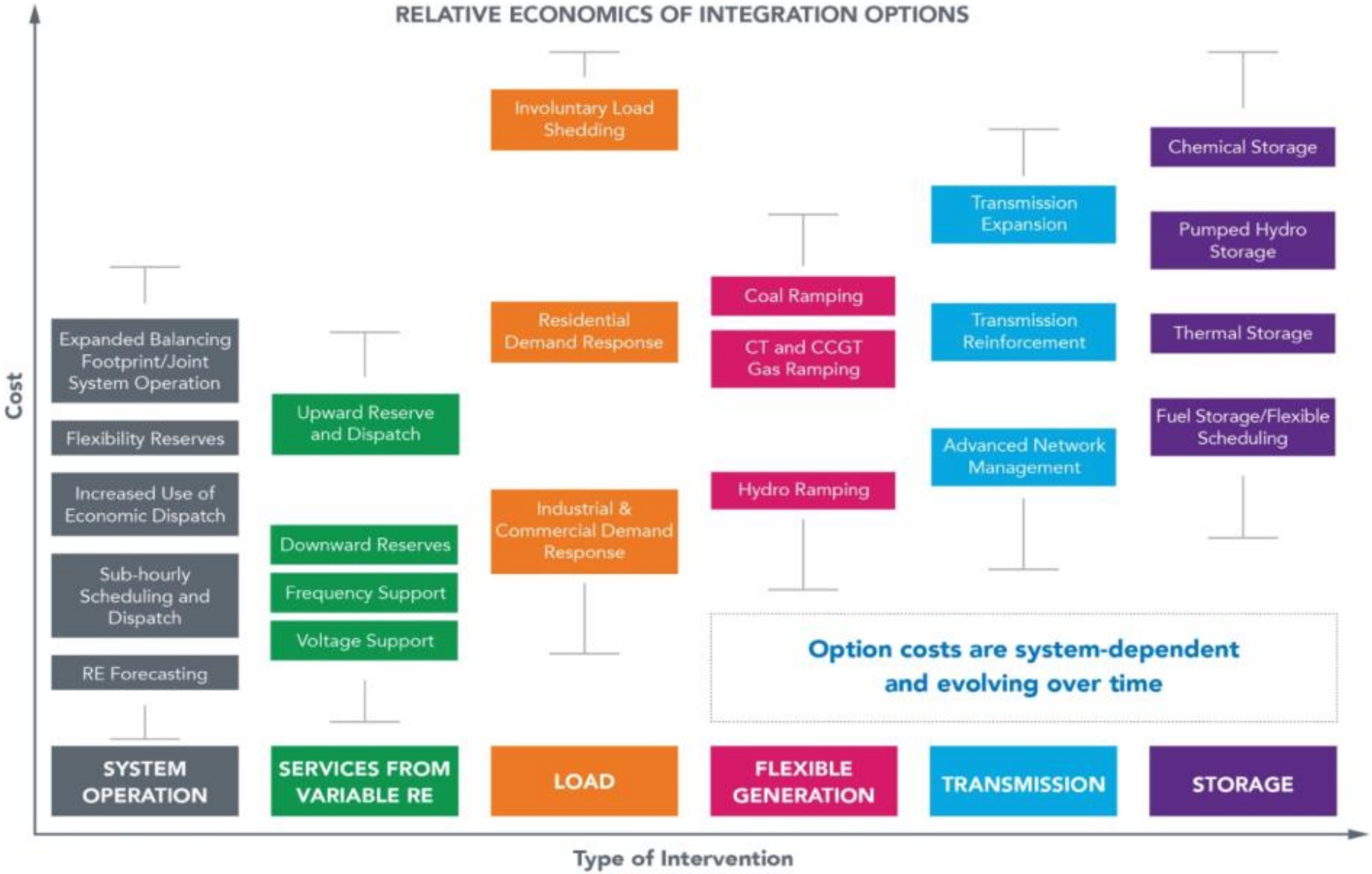
Why is the last 10% difficult and expensive?

- The balance challenge – a mismatch of RE supply and demand
- The inverter challenge – supplying the necessary grid services from inverter based resources

Timescales of the Balance Challenge



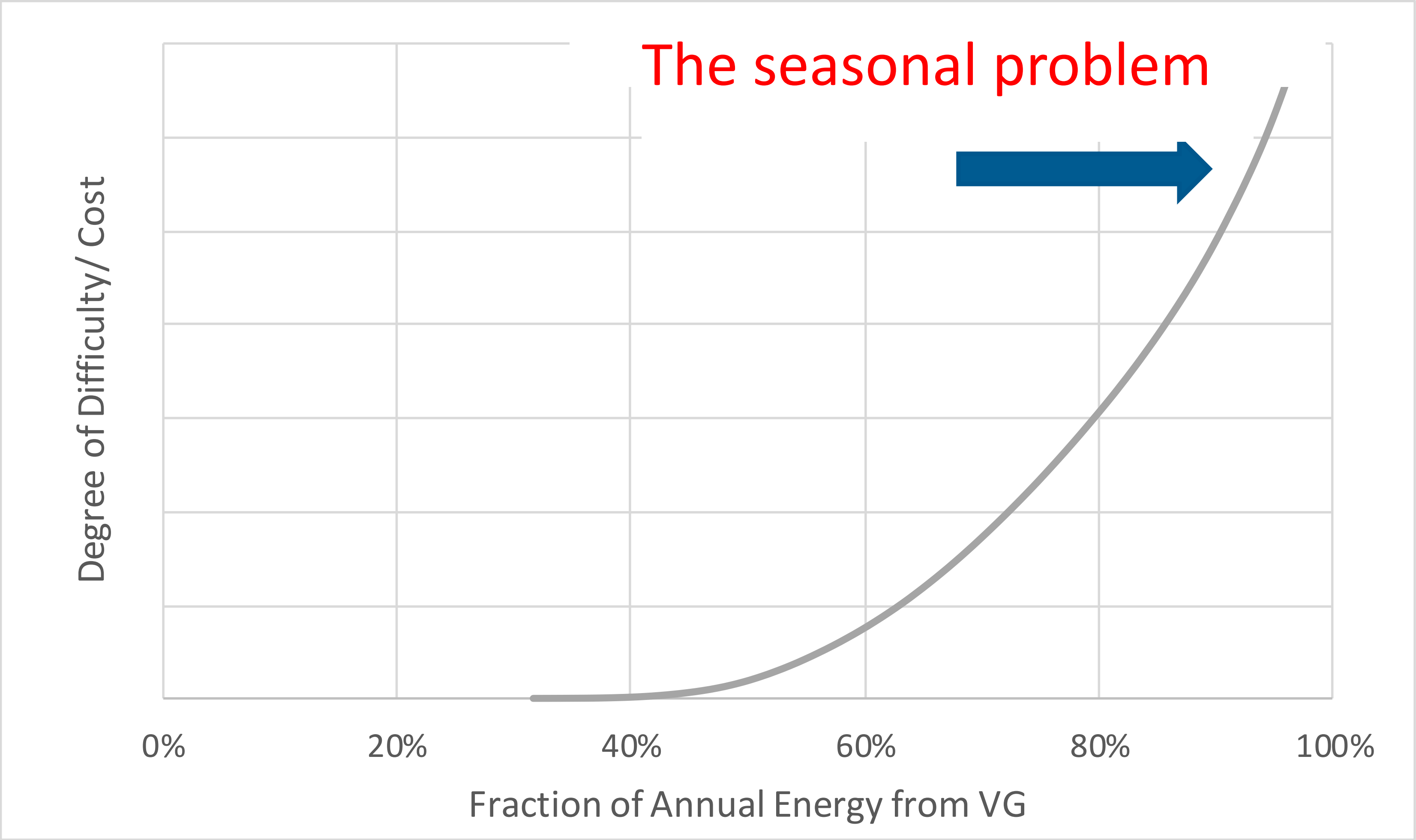
Possible Solutions for Dealing with The Balance Challenge



Solutions:

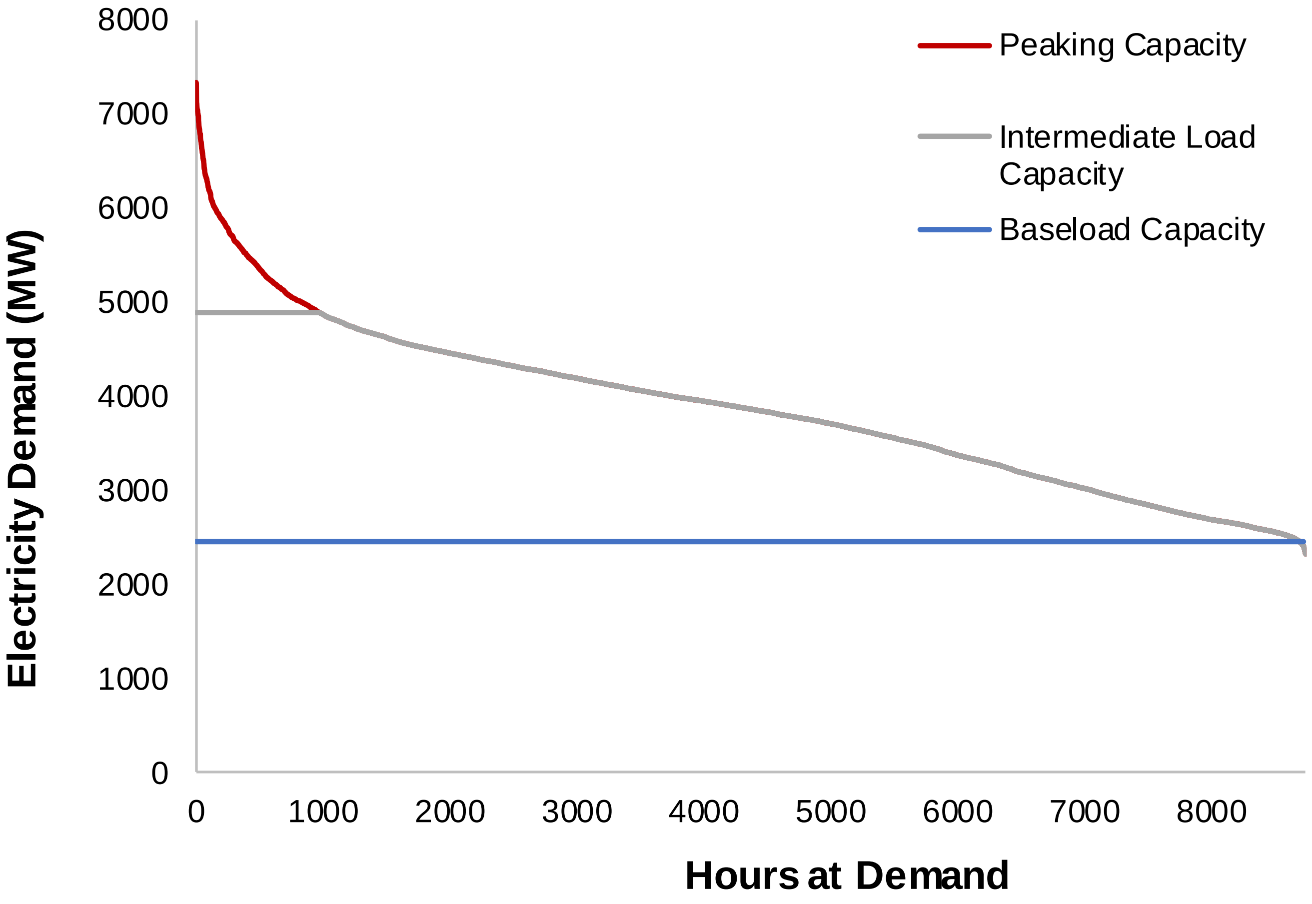
- Utilize geographic diversity
- Better VRE Forecasting
- Better dispatching of entire generation fleet
- Increase sharing among balancing authority areas
- VRE providing grid services
- Coordinate flexible loads (active demand response)
- Utilize flexible conventional generation
- Transmission management and expansion
- Curtail excess VRE production
- Electrical storage
- Interact with other energy carriers

Timescales of the Balance Challenge

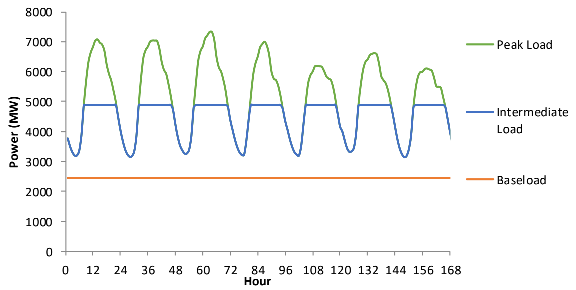


So what is the problem here?

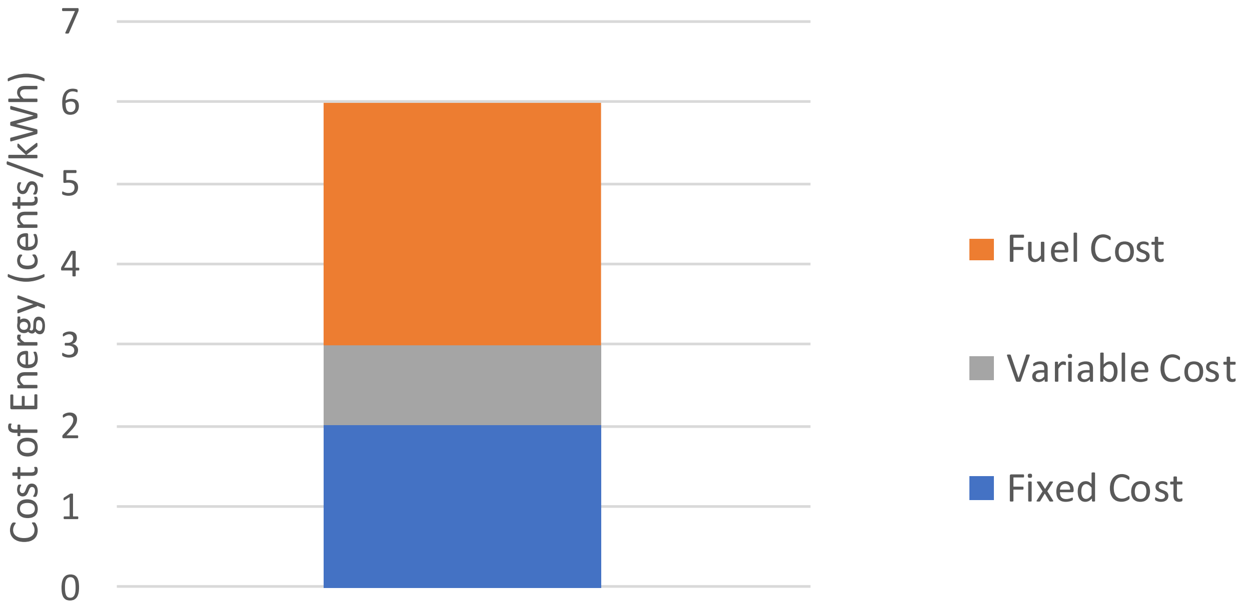
Reminder – The Last 10% Has Always Been Expensive Due to the Seasonal Problem



This "third" of the power plant fleet provides about 2% of total annual energy demand



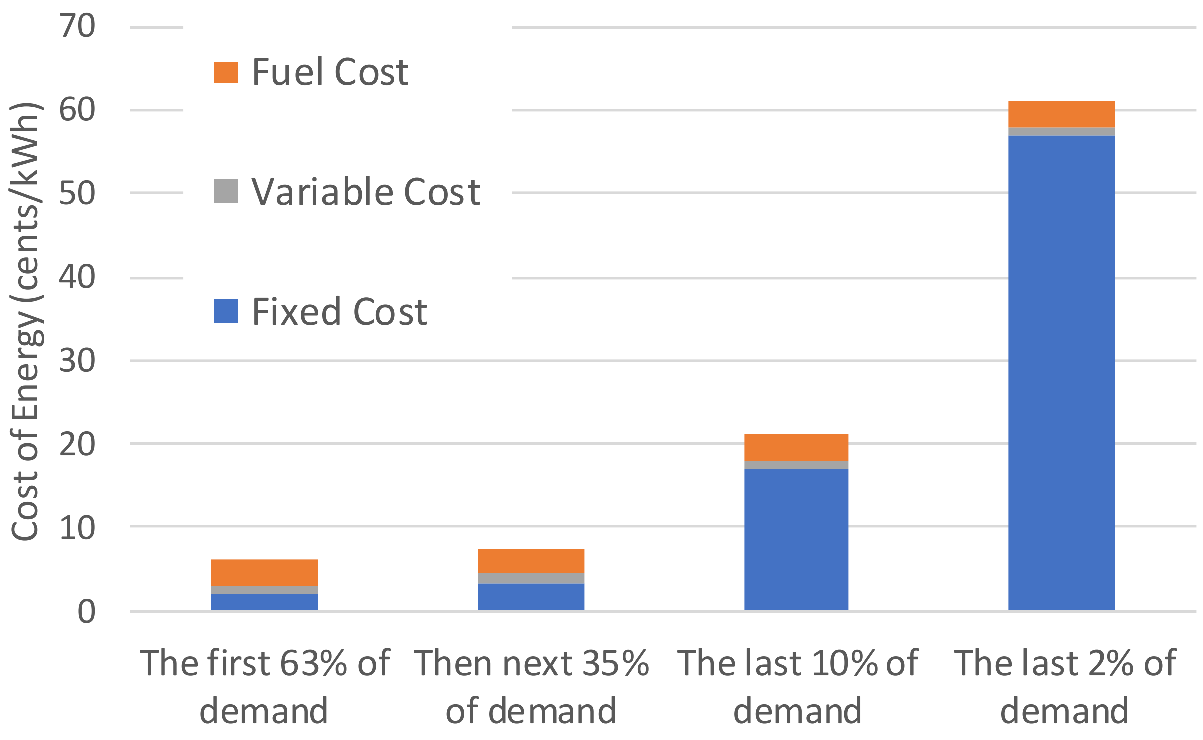
Its all about utilization….



Example scenario:

A 100 MW gas-fired power plant costs $15 Million per year (fixed costs). Run at at 90% capacity factor, this produces an LCOE of 6 cents/kWh

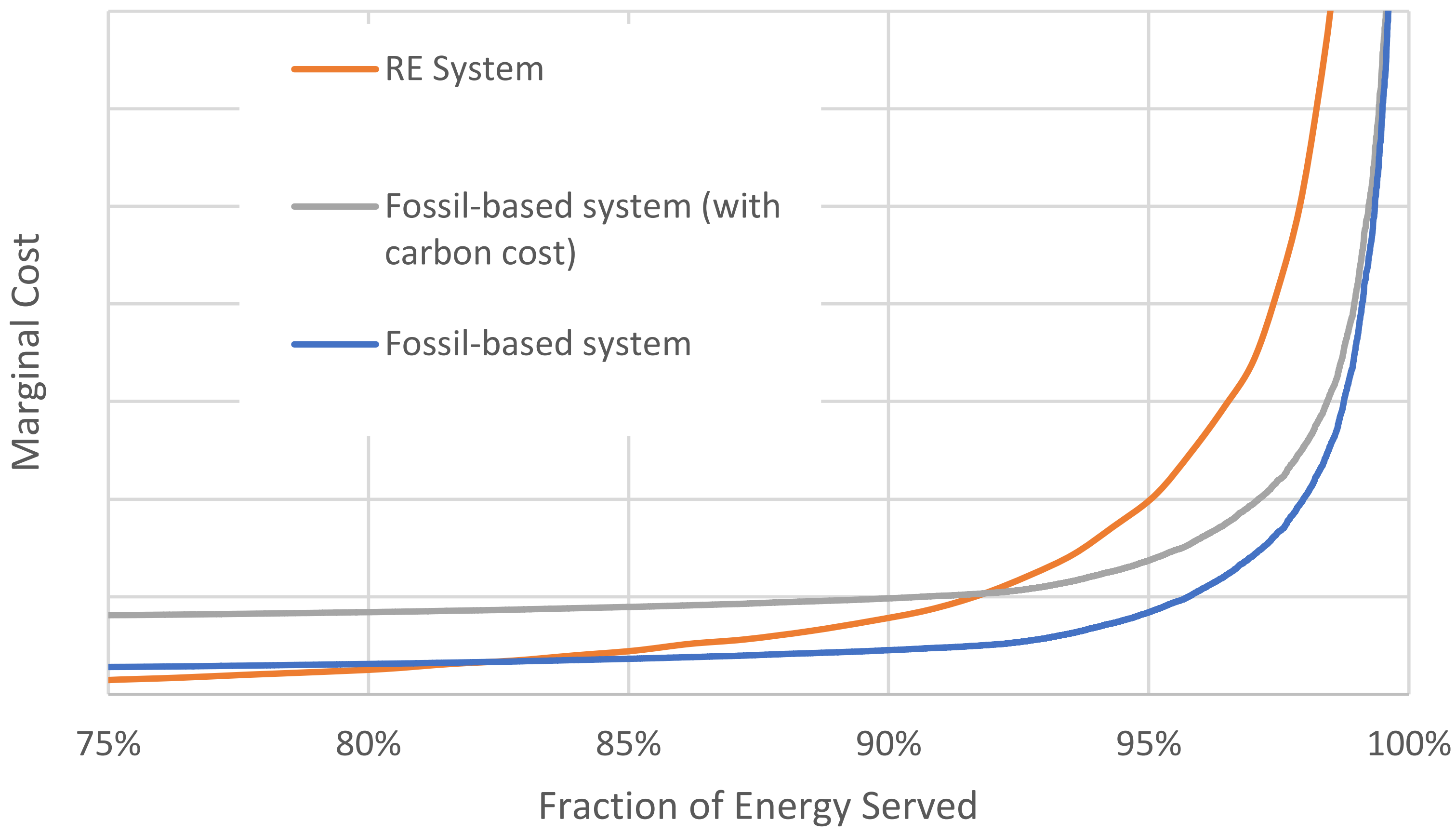
The Cost of Gas-Fired Peaking Energy



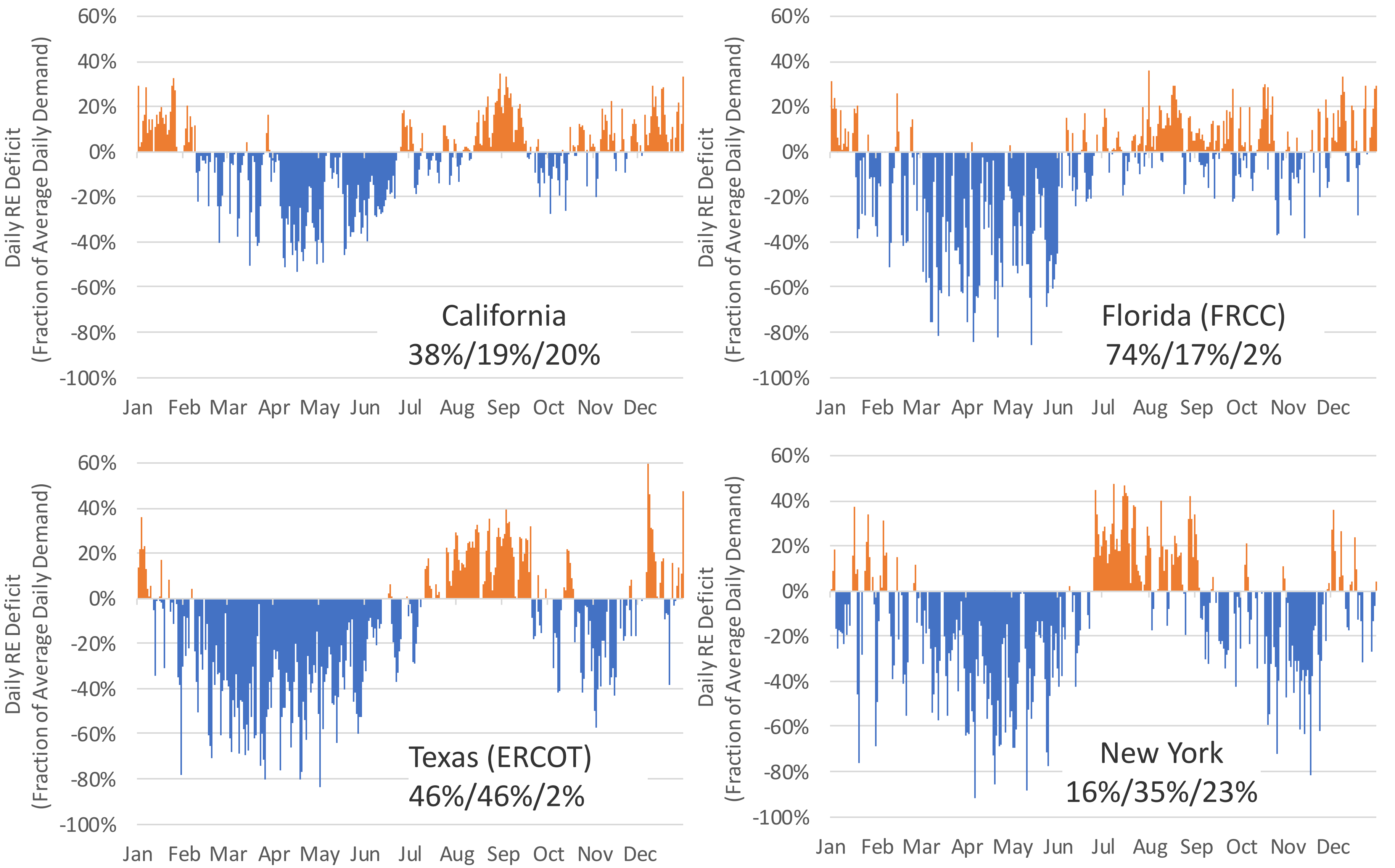
As the capacity factor drops, the LCOE increases. Meeting the last 10% costs >20 cents/kWh

And meeting the **last 2%** of energy demand costs **60 cents/kWh** mostly to meet fixed generation costs

Capacity Factor (and Capacity Credit) of Wind and PV with Diurnal Storage Drops



Example of the balance challenge approaching 100% RE systems



Each region meets 95% of annual demand with RE.

Fraction in each location is PV / wind/ hydro and other RE.

Three General Classes of Solutions

- RE and diurnal storage
- Demand response
- Seasonal storage
- Maybe a fourth?

1- Low Cost Renewables and Diurnal Storage

- Really cheap RE means it is still cost competitive even with very high curtailment rates
- Beyond 95% RE might require 1 cent/kWh wind and solar and <<$100/kWh storage

2- Load Flexibility

- Improved alignment of electricity demand with supply.
  - Controlled EV charging
  - Smart Buildings and IoT technologies responding to real time prices or other advanced controls that minimize cost.
  - Many of these technologies allow for diurnal shifting. Role of multiday or seasonal shifts are unclear.

3- Seasonal Storage and Fuels Production

- Use of low-value off-peak or off-season RE generation to produce a gas or liquid fuel
  - Process starts with production of electrolytic hydrogen, then potentially up conversion to higher density and easier to store/transport chemicals including methane, ammonia, or other hydrocarbons
  - Used to generate electricity via combustion turbine or fuel cells
  - Multi-sector applications including transportation fuel, industrial process heat
  - Also a feedstock for industrial processes including chemicals, plastics

4- Declare Victory and Go Home

- Get to 95% and get the rest of the carbon out of the system via direct air capture, biomass CCS, carbon free fuels from fossil CCS, nuclear

Thank you

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