

# Flexible Load In Deeply Decarbonized Electricity Systems

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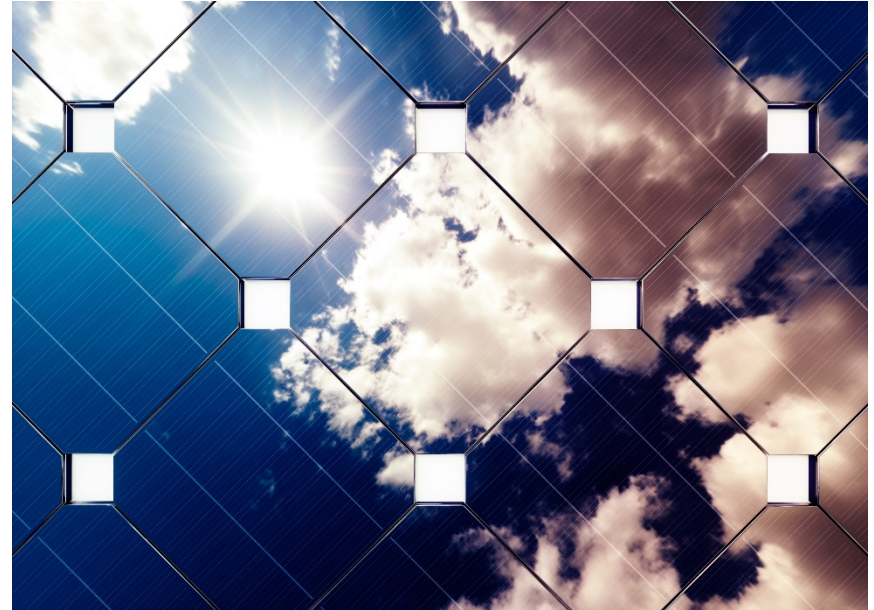
# About Evolved Energy Research

- Energy consulting firm focused on addressing key energy sector challenges posed by climate change
- Members of the research team representing the U.S. in the Deep Decarbonization Pathways Project
- Lead developers of EnergyPATHWAYS



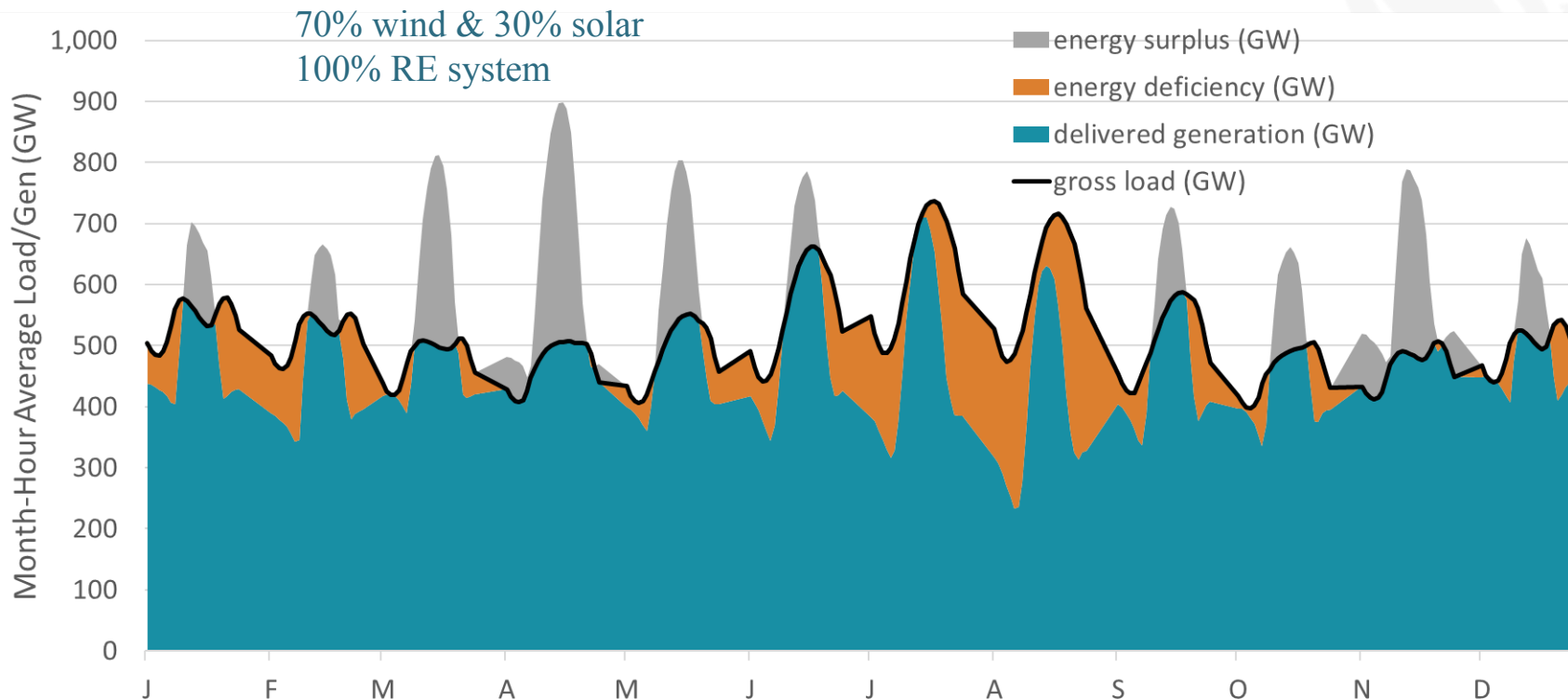
# Need for Flexible Loads

- Traditional electricity operations have assumed fixed load and utilize controllable or ‘dispatchable’ generation resources
- We lose economic control of generation in in deeply decarbonized electricity systems with high wind & solar
- The loss of control on the supply-side necessitates the introduction of flexible loads to manage the balance of supply and demand on all timescales



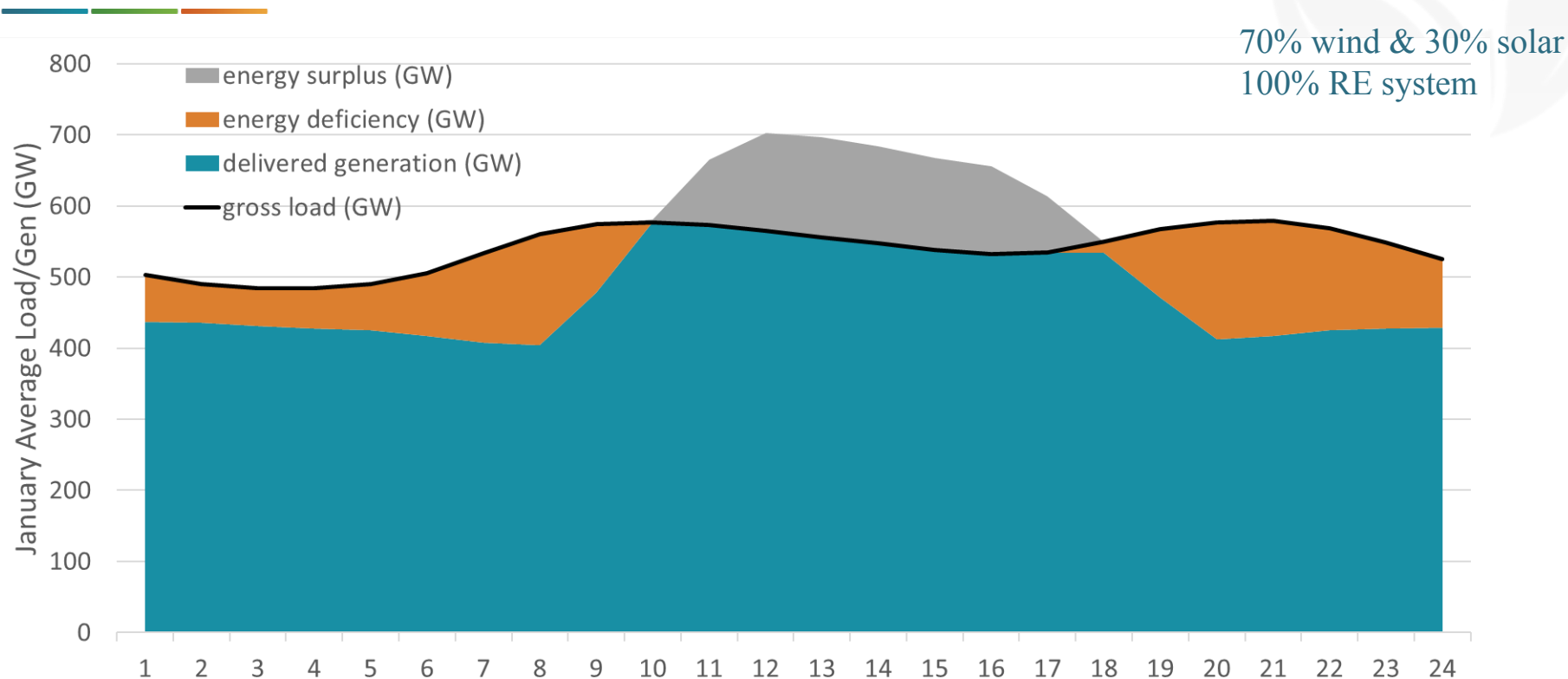
# Average energy imbalance by month-hour

Eastern interconnection using load and renewable profiles from 2011



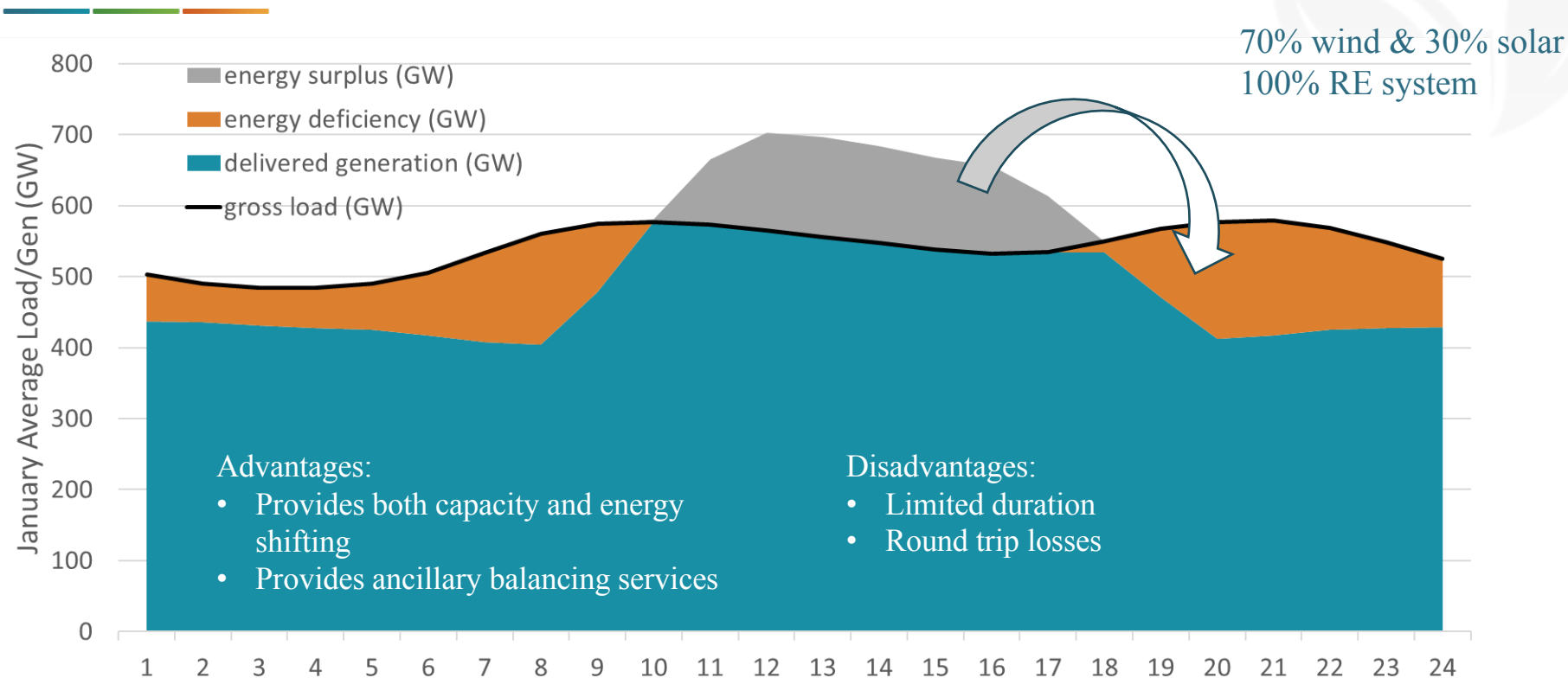
# Defining energy imbalance

Eastern interconnection using load and renewable profiles from January, 2011



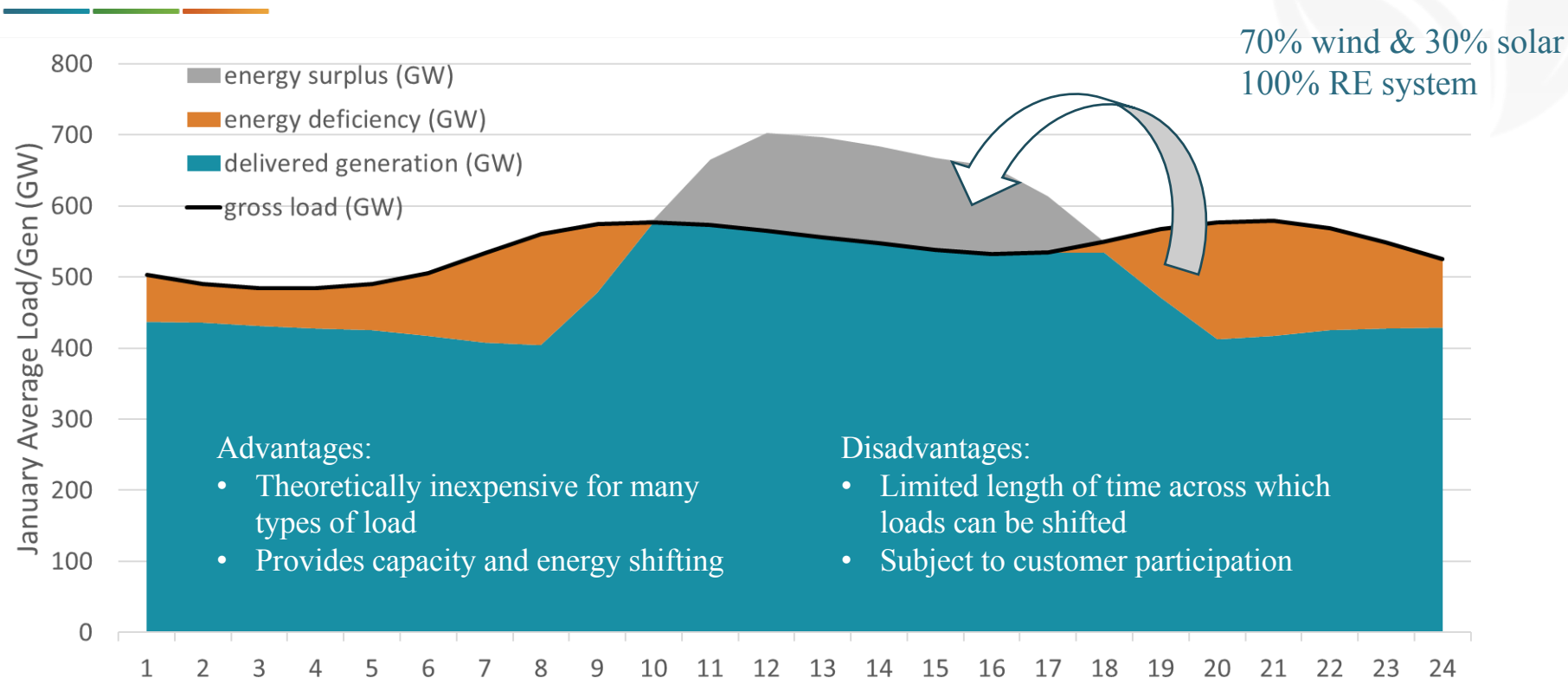
# Option 1: Use storage load to shift the grey to the orange

Eastern interconnection using load and renewable profiles from January, 2011



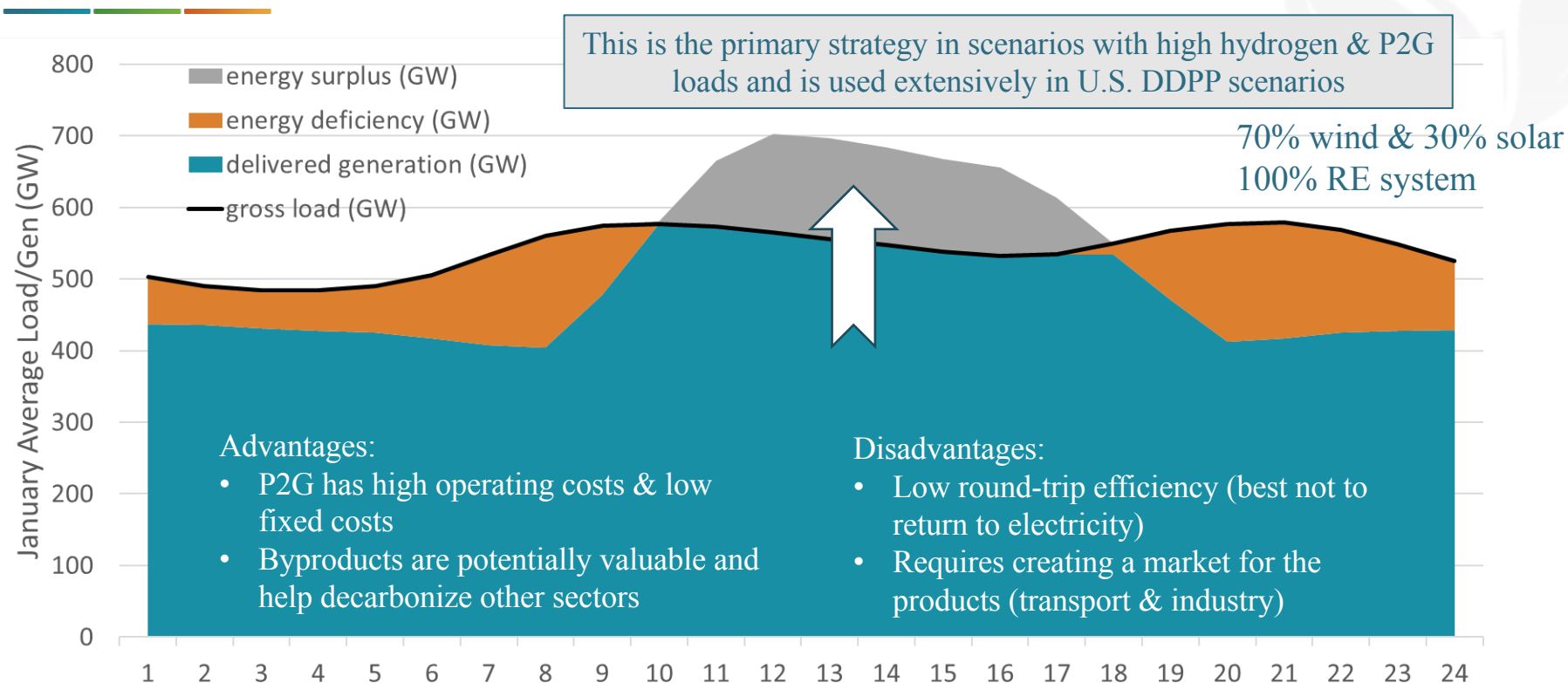
## Option 2: Use end-use loads flexibly to shift the orange to the grey

Eastern interconnection using load and renewable profiles from January, 2011



# Option 3: Build dedicated load into the grey and build more renewables

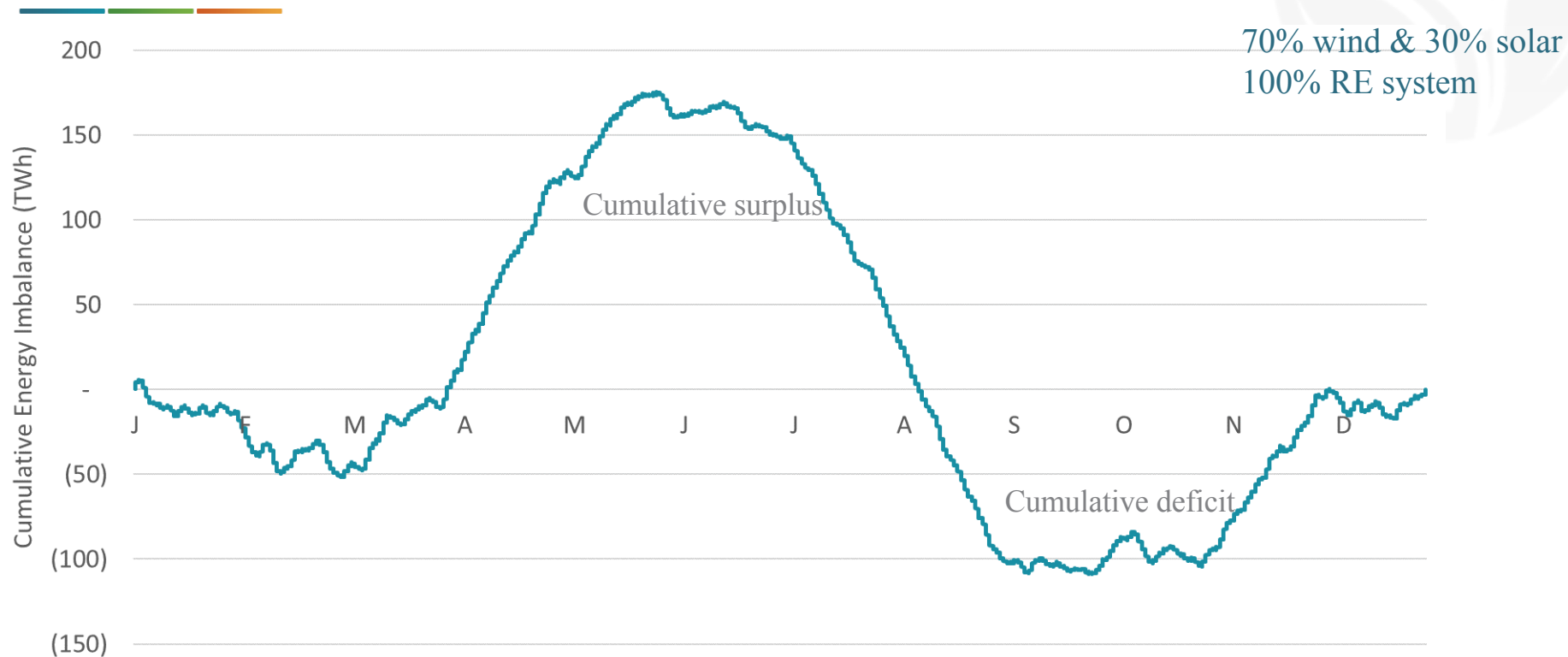
Eastern interconnection using load and renewable profiles from January, 2011





# How does imbalance cumulate over the year?

Timescales of cumulative energy imbalance show how energy must be shifted across the year



# Key takeaways



- Grid balancing issues are diverse, complex, and depend on the particulars of any system
- **There is no single demand-side balancing solution...**
  - Relying exclusively on end-use loads alone would degrade service
  - Storage is necessary but not sufficient for seasonal issues
  - Loads like power-to-gas have high losses and require demand for their products
- **...but a potential role exists for all**
  - End-use loads can manage system imbalance and reduce distribution system infrastructure needs
  - Storage is controllable and represents the platonic ideal of a balancing resource for short and medium-term imbalances
  - Dedicated loads like power-to-gas can address seasonal issues