Big, Fast, and Flexible: Grid Operations for Efficient Variable Renewable Integration

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Learning objectives

- Recognize how the speed of power system operations and the size of the balancing area footprint affect power system flexibility and enable variable renewable energy (VRE) integration
- Distinguish various approaches to increasing power system flexibility under market and non-market institutional contexts
- Identify policy and other actions to improve grid operations for efficient variable renewable energy integration

Outline

- Power system operation and VRE integration– what are the basics?
- Flexible power systems: the principles of big and fast
- Alternative approaches to coordination among balancing regions
- Examples of pathways to achieve “big and fast” under different institutional contexts

Where are we?

- **Power system operation and VRE integration– what are the basics?**
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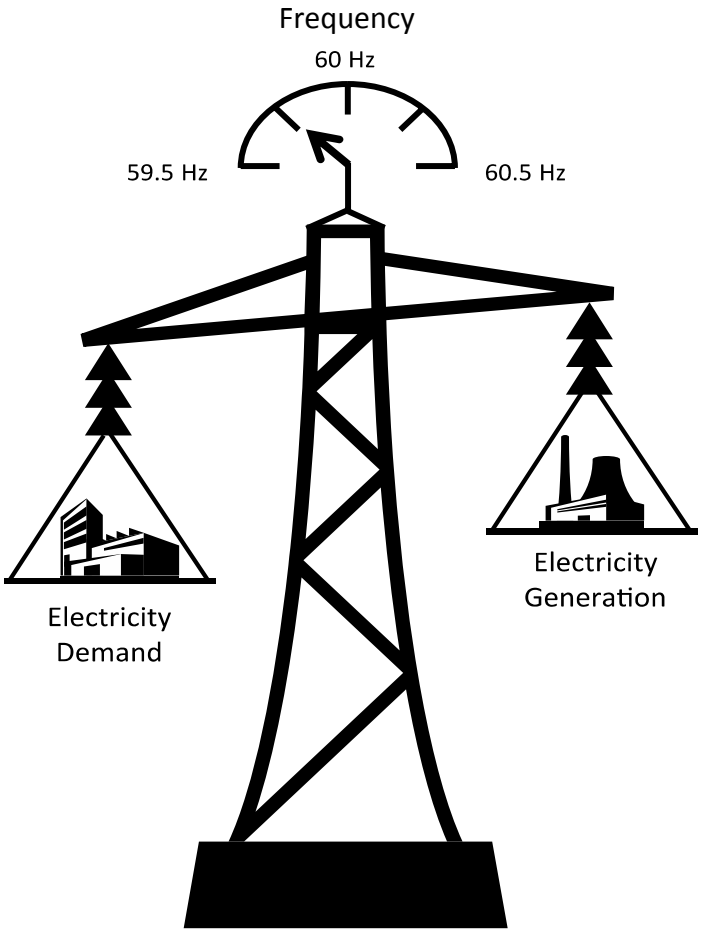
Power System Objectives

Supply electric power to customers

- Reliably
- Economically

Consumption and production must be ***balanced <u>continuously</u> and <u>instantaneously</u>***



Maintaining system frequency is one of the fundamental drivers of power system reliability

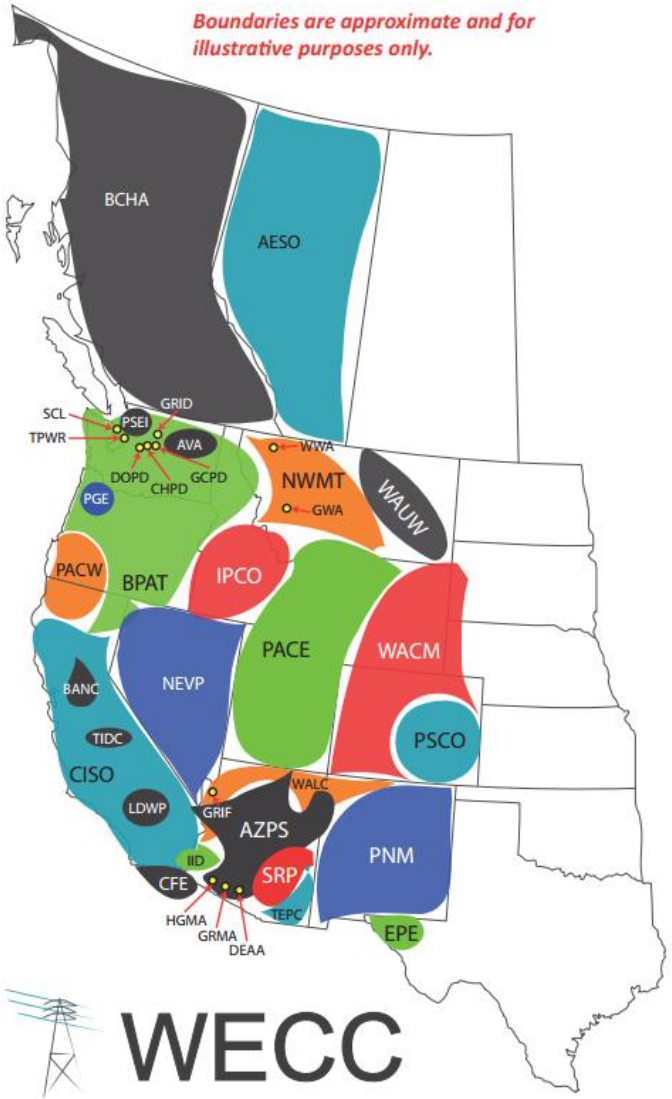
Slide credit: B. Kirby

What is a balancing authority?

Responsible for controlling electricity transmission flows and maintaining system **voltage and frequency** within certain limits

- **Ancillary services** are used to support reliable system operations in the case of a disturbance, such as an unplanned generator outage or line disruption

- **Reserves** are an important ancillary service that consist of unloaded generation and demand response that can be quickly dispatched

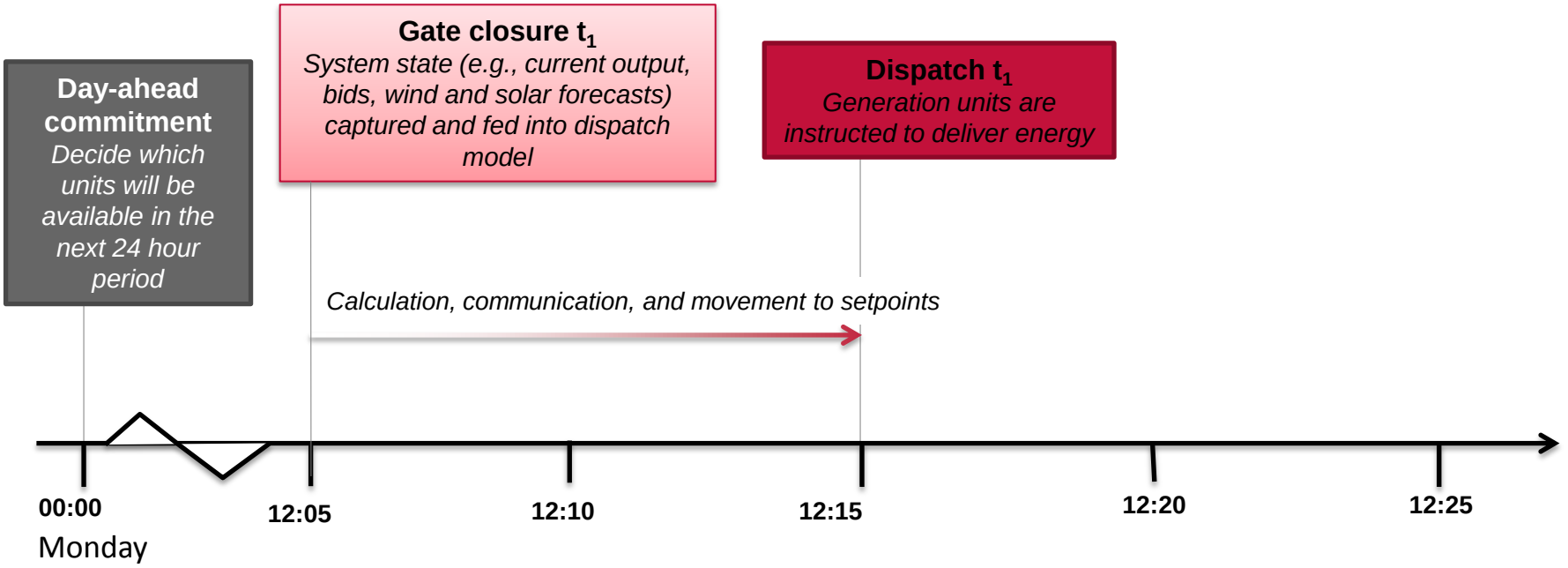


Source: Western Electricity Coordinating Council

Time horizons of power system operation

- ***Unit commitment/scheduling***: the amount of time before power system operators need to start generators so that they are available when needed to meet demand (e.g., day-ahead, hour-ahead).
- ***Gate closure***: the point at which the most recent actual data (operational, market) is no longer collected, and setpoint calculation/communication process begins (e.g., 1+ days ahead, hour-ahead, minutes-ahead).
- ***Dispatch*****:** the frequency with which the power system operator chooses among available generators to deliver energy (e.g., hourly, 15-min, 5-min).

Example system with 5-minute dispatch:



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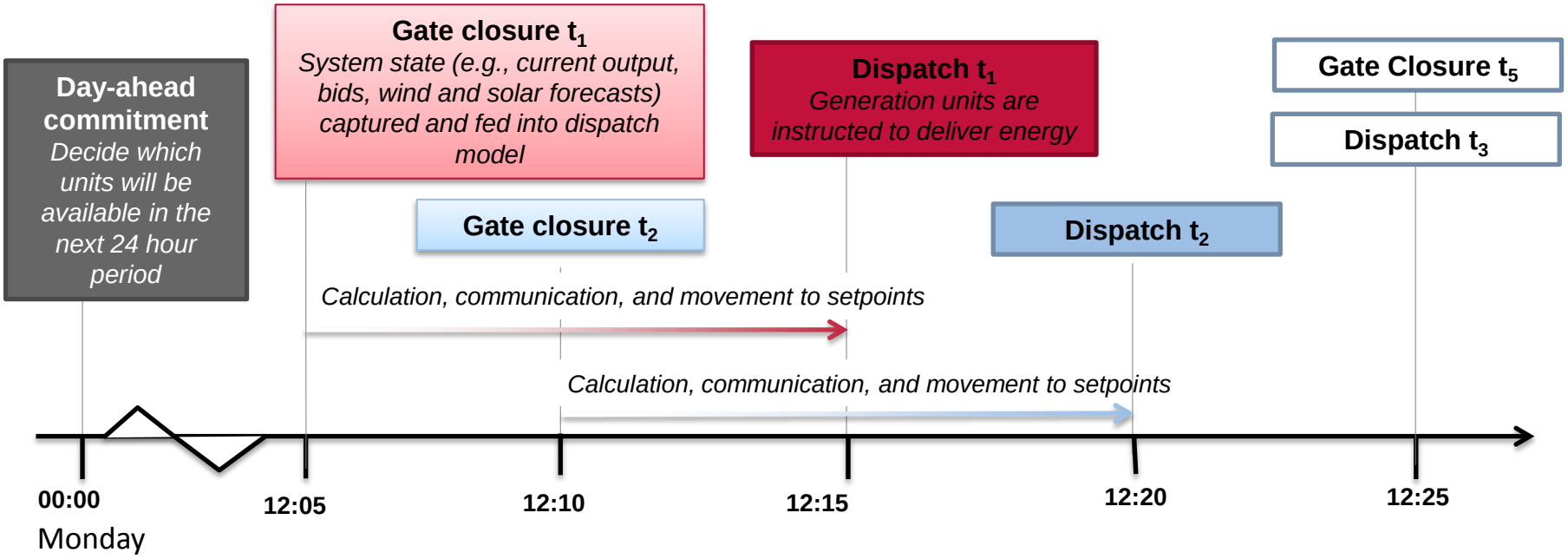
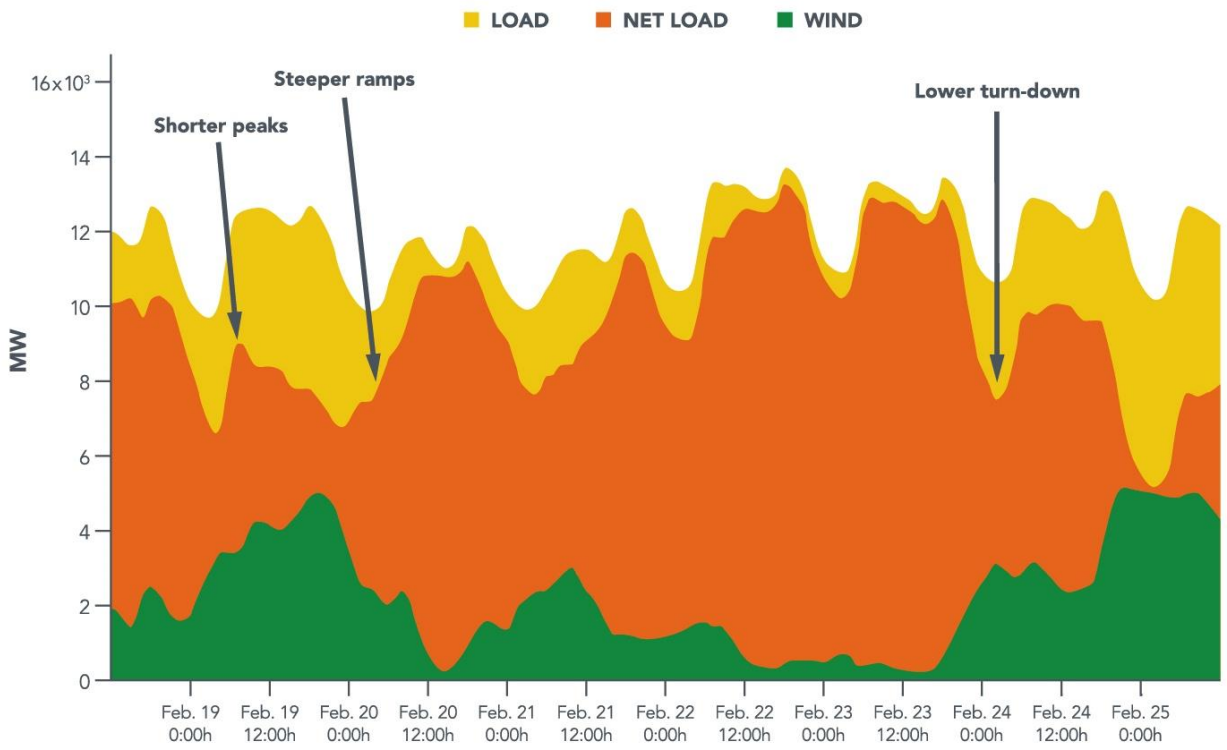


Why is grid integration important?

- Wind and solar are variable – the wind and sunlight change.
- Wind and solar energy are uncertain – we can forecast them reasonably well for time periods ranging from minutes, hours, a few days.
- **Grid integration** is the practice of developing efficient ways to deliver high penetration levels of variable RE to the grid.
- The variable and uncertain nature of wind/solar require additional power system flexibility…

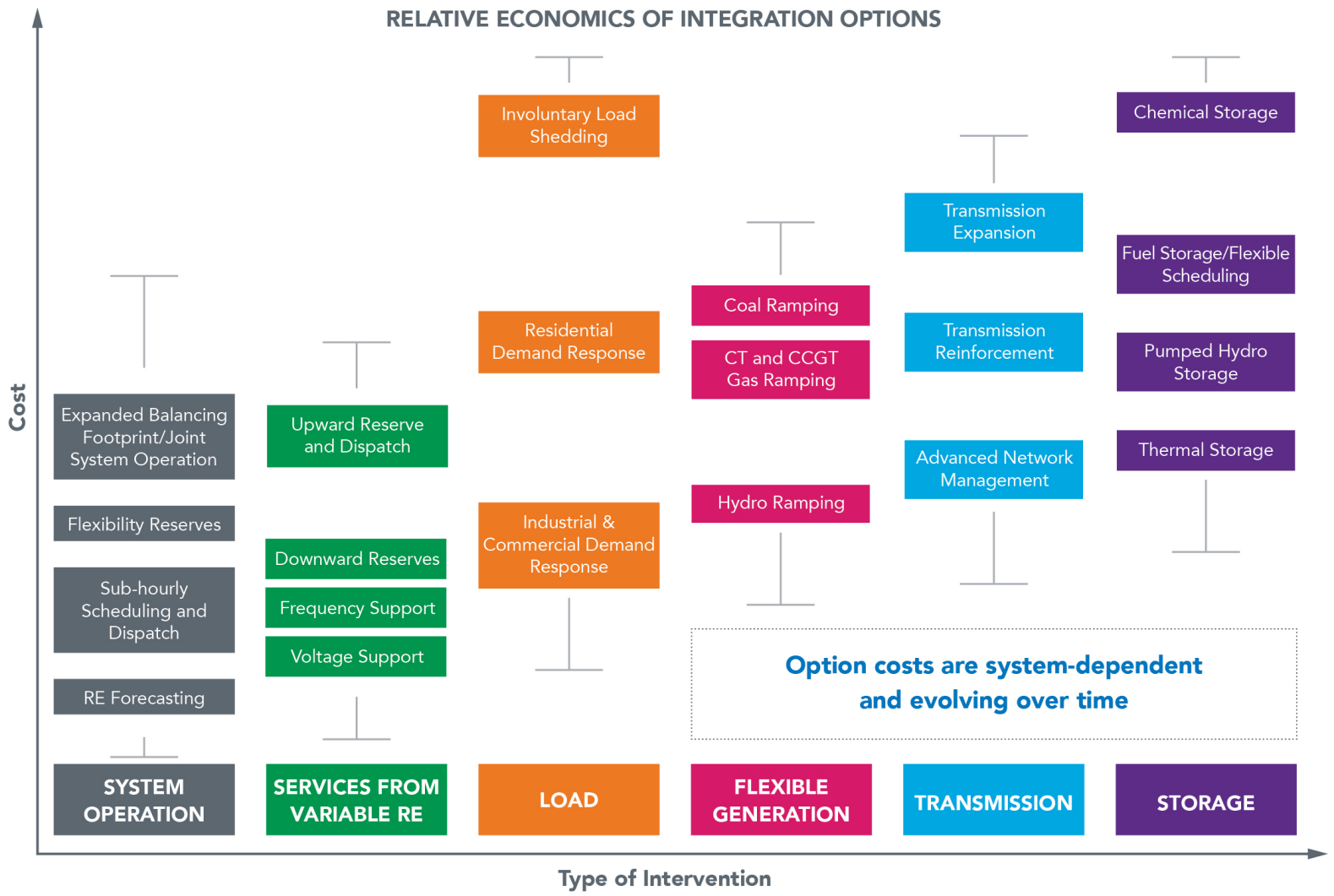
“Flexibility” can help address the grid integration challenges

***Flexibility**: The ability of a power system to respond to change in demand and supply*



- Increases in variable generation on a system increase the variability of ‘net load’
  - ‘Net load’ is the demand that must be supplied by conventional generation
- High flexibility implies the system can respond quickly to changes in net load.

Frequently used options to increase flexibility



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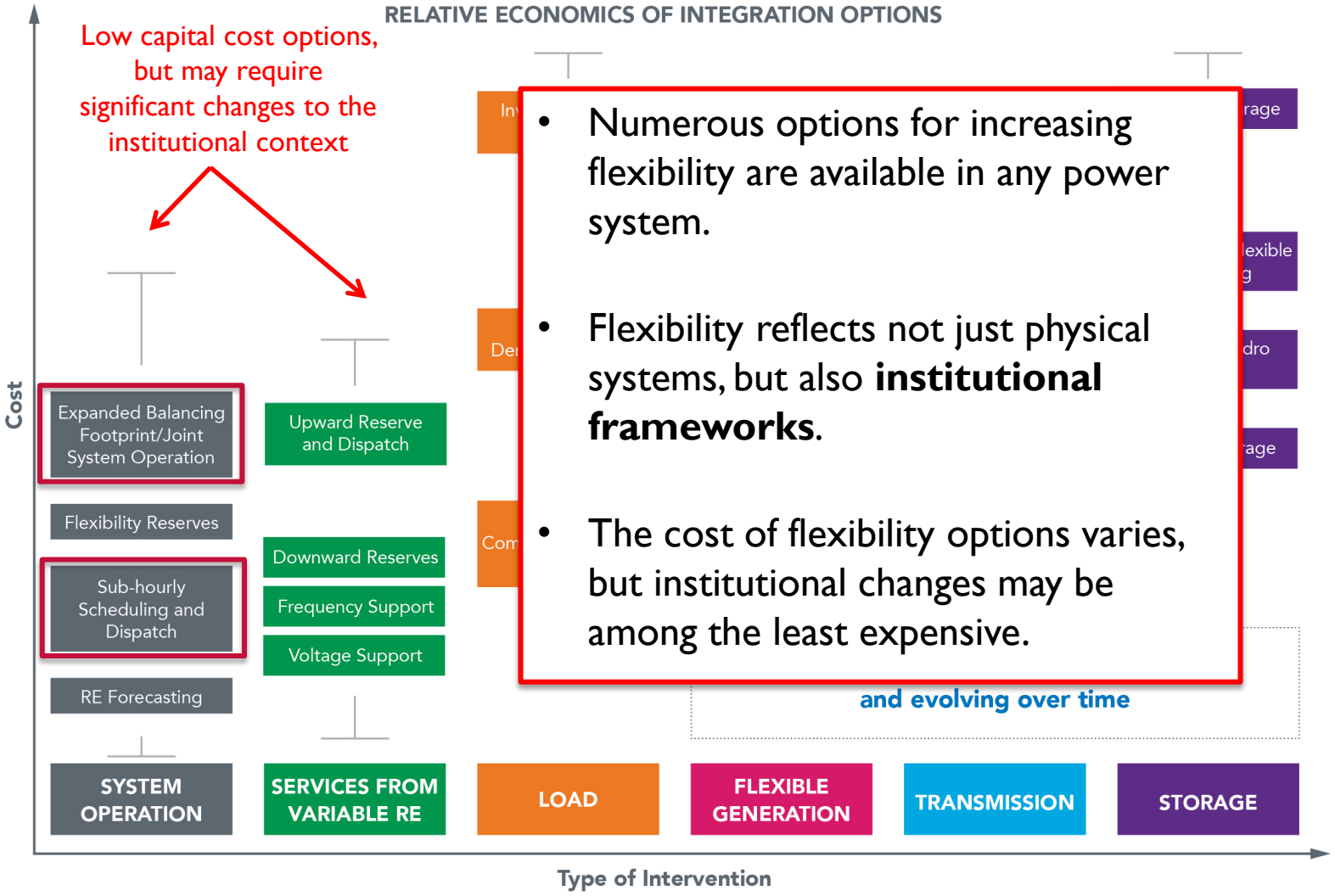

- Numerous options for increasing flexibility are available in any power system.
- Flexibility reflects not just physical systems, but also **institutional frameworks**.
- The cost of flexibility options varies, but institutional changes may be among the least expensive.

Where are we?

- Power system operation and VRE integration– what are the basics?
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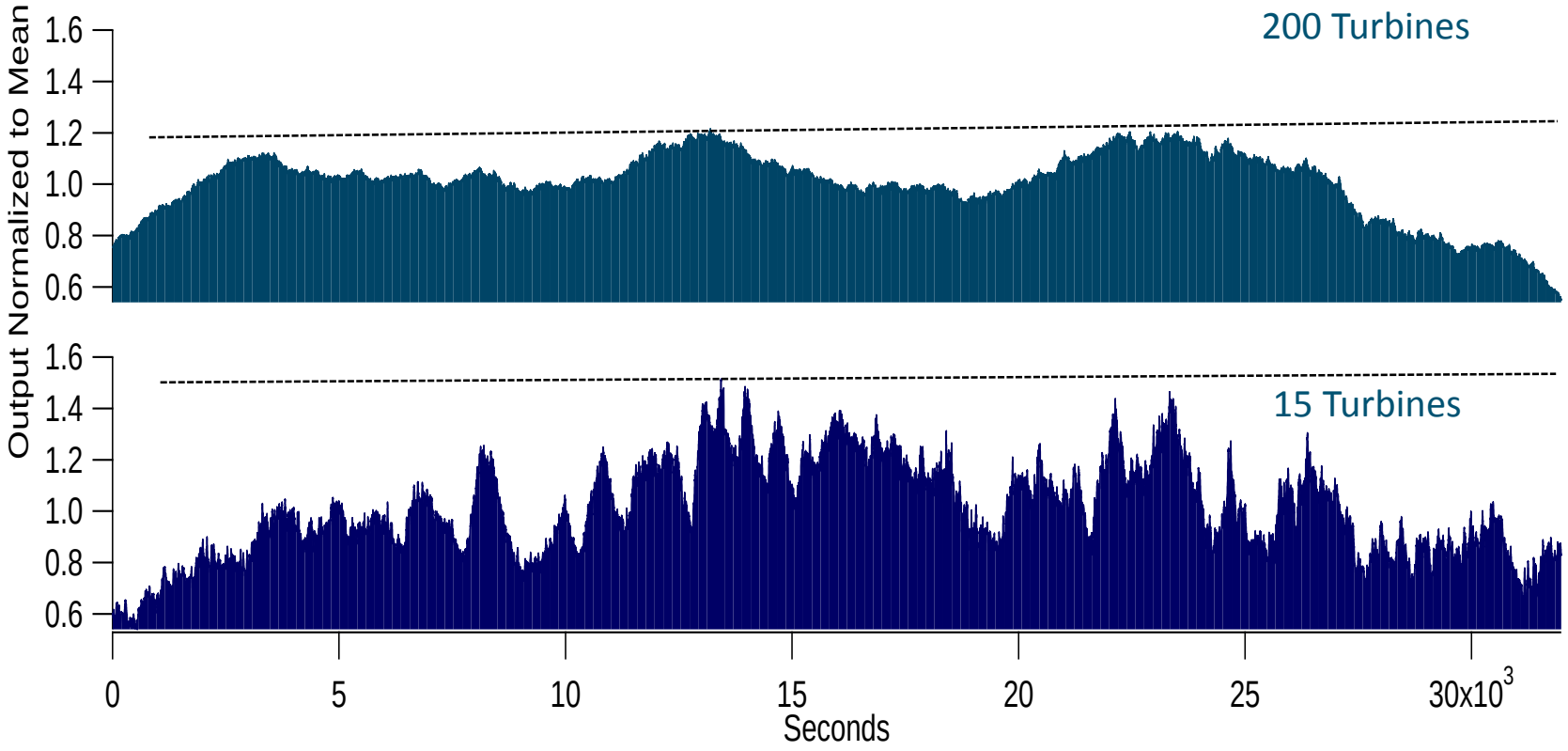
Geographic diversity can reduce variability and need for reserves

Bigger balancing footprint

Aggregation and geographic diversity reduces the variability of wind energy

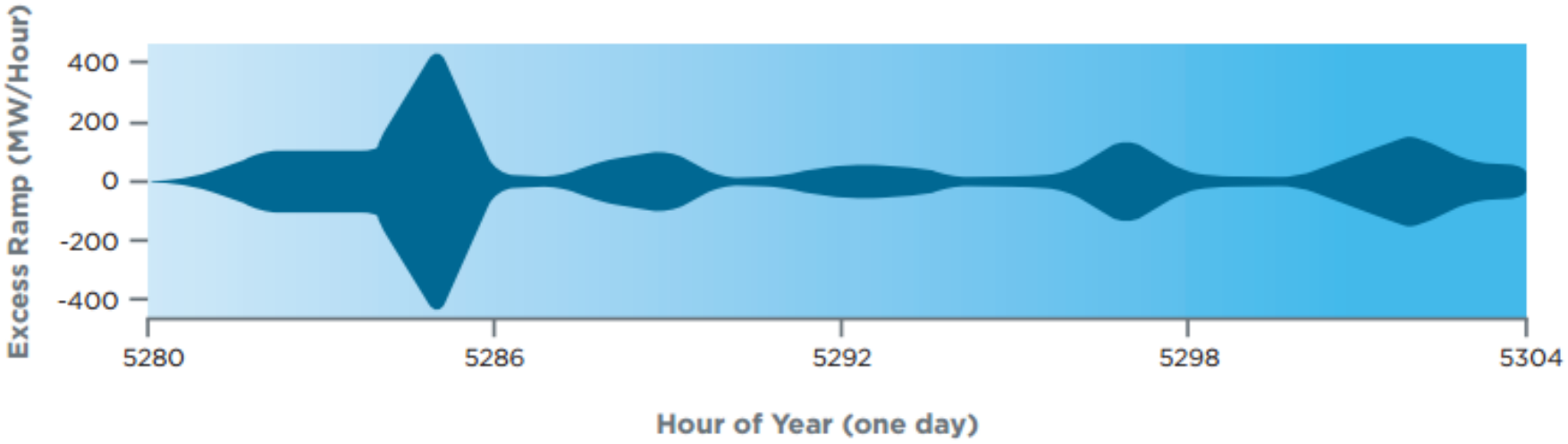


Source: NREL wind plant data

Approximately 8 hours

How does a larger balancing area support RE integration?

Bigger balancing footprint



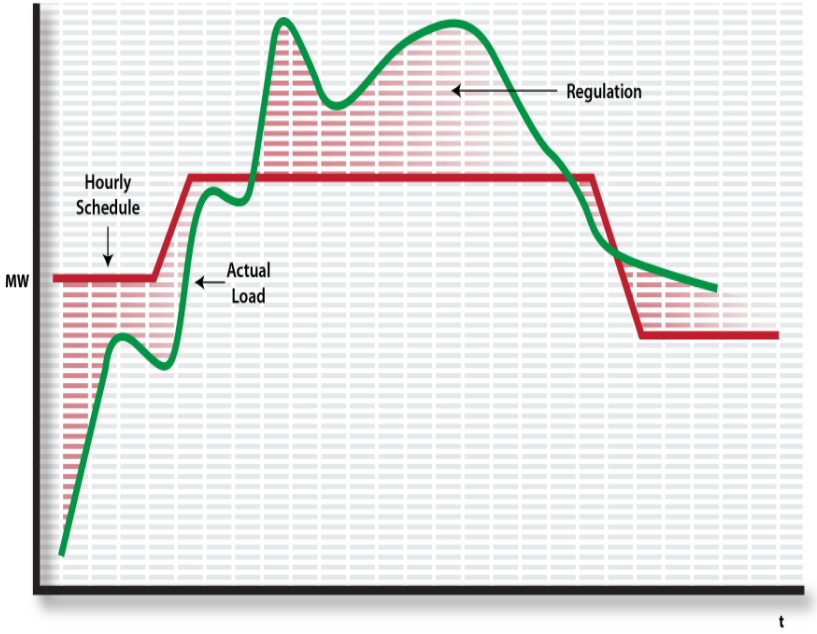
- Example: Balancing area A is ramping up 600 MW, at the same time that Balancing Area B is ramping down 400 MW.
- Combining these balancing areas can eliminate 400 MW of ramping up and down
- Balancing area A and B can each ramp 1000MW/hour. Combined, they can ramp at 2000MW/hour. Ramping capability increases more than ramping needs.

Source: Milligan & Kirby, NREL, http://www.nrel.gov/docs/fy07osti/41809.pdf

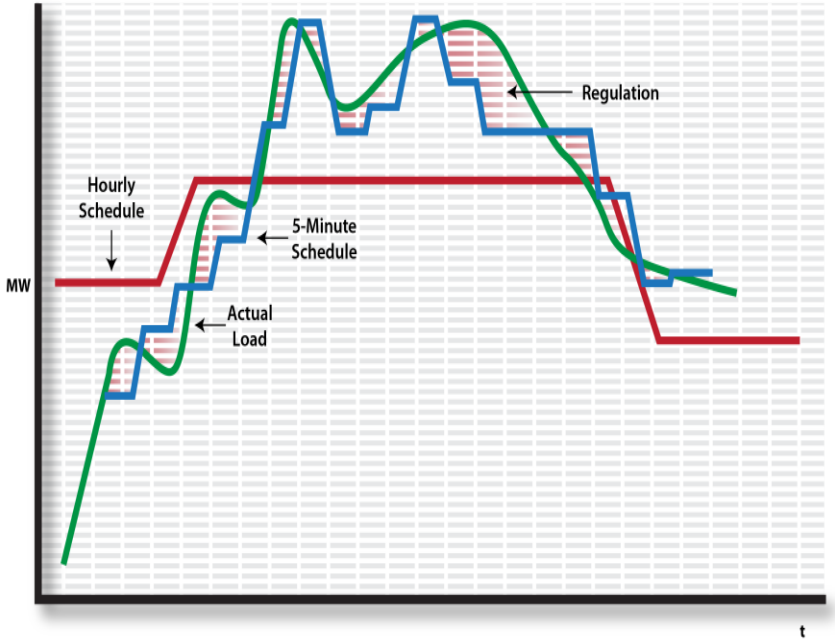
How does faster scheduling support RE integration?

Faster gate closure and dispatch

Hourly schedules and interchanges



Sub-hourly scheduling



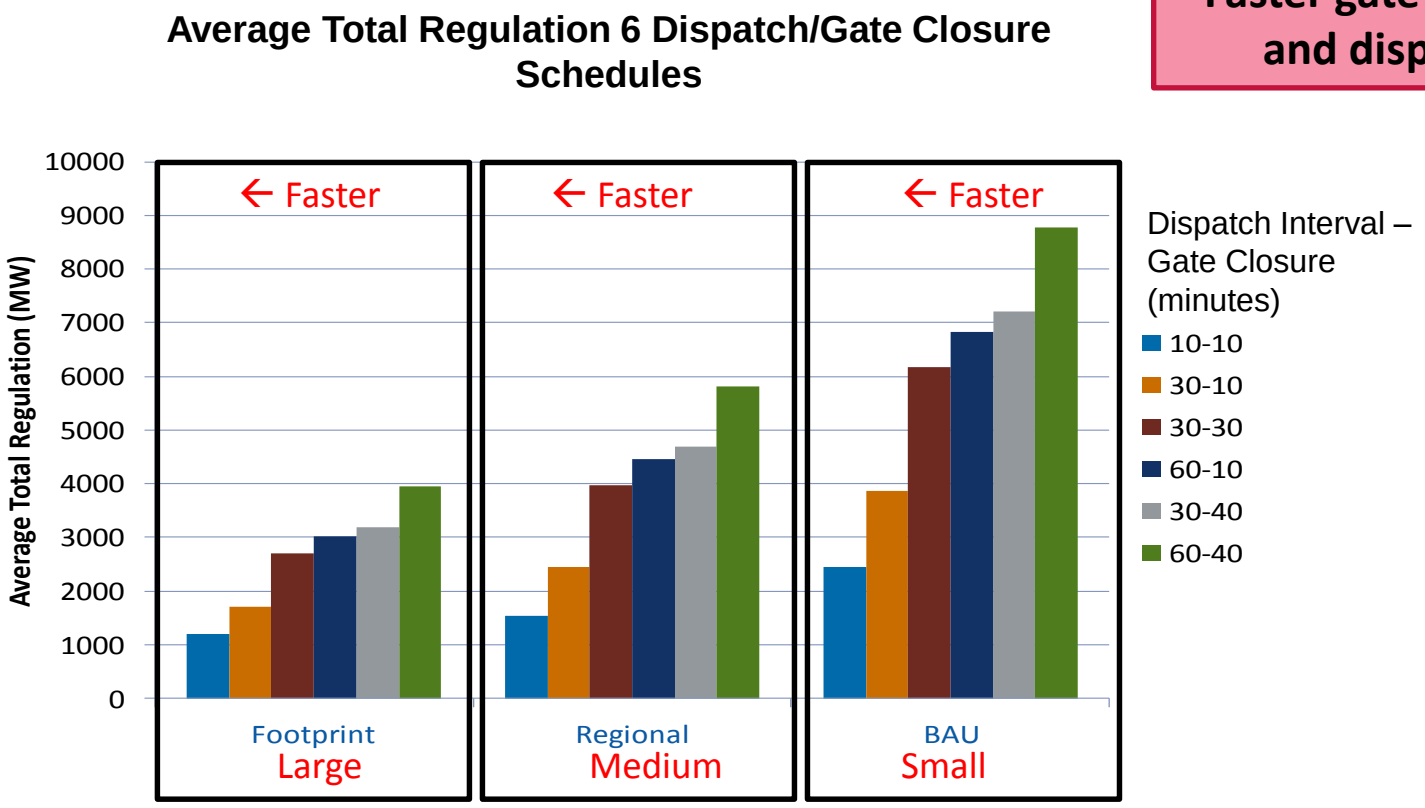
Source: NREL

- Making scheduling and dispatch decisions closer to real-time reduces uncertainty and the need for expensive ancillary services
  - ✓ Increase flexibility and reduce system costs
- Better alignment with the timescale of variable RE resources, enabling better utilization of wind and solar forecasts
  - ✓ Reduce wind and solar curtailment

Big and fast in combination: Impacts of faster dispatch, shorter gate closure, and larger balancing areas

Bigger balancing footprint

Faster gate closure and dispatch



Milligan, Kirby, King, Beuning (2011), The Impact of Alternative Dispatch Intervals on Operating Reserve Requirements for Variable Generation. Presented at 10th International Workshop on Large-Scale Integration of Wind (and Solar) Power into Power Systems, Aarhus, Denmark. October

- Large, agile systems can more cost-effectively integrate high quantities of variable wind and solar
- Faster interchange has a similar impact as faster dispatch

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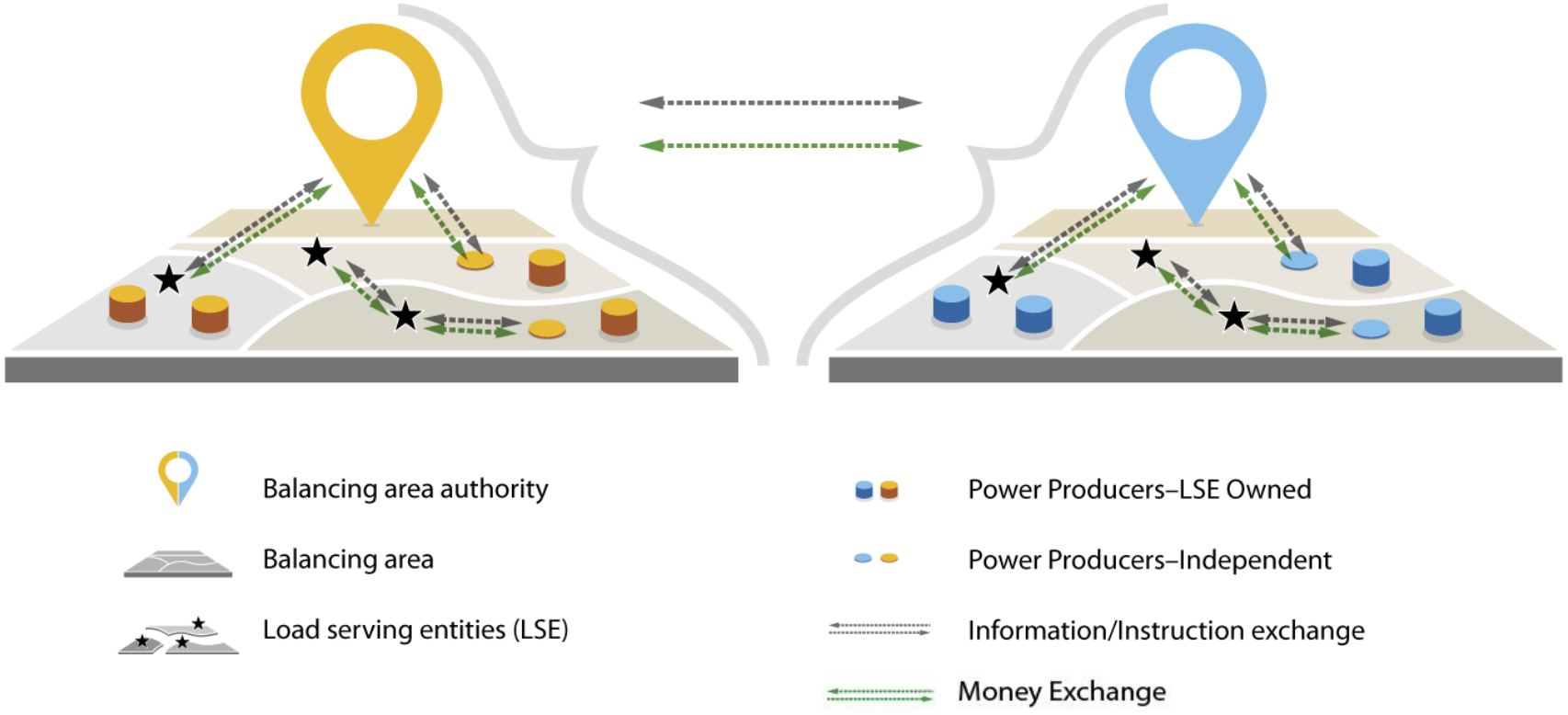
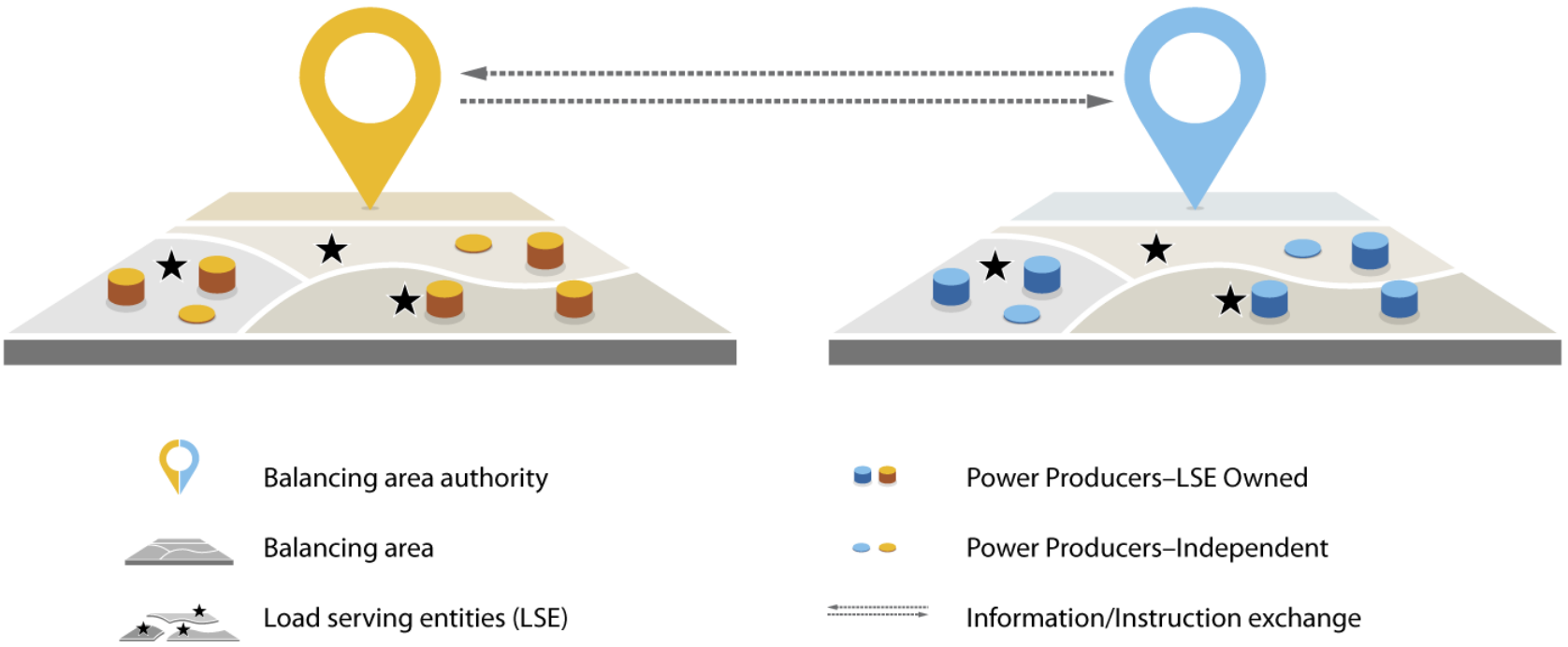
Uncoordinated balancing areas (typical operations)

- Each balancing area authority balances supply and demand within its own geographic boundary, with limited imports and exports



Balancing area coordination: Reserve sharing

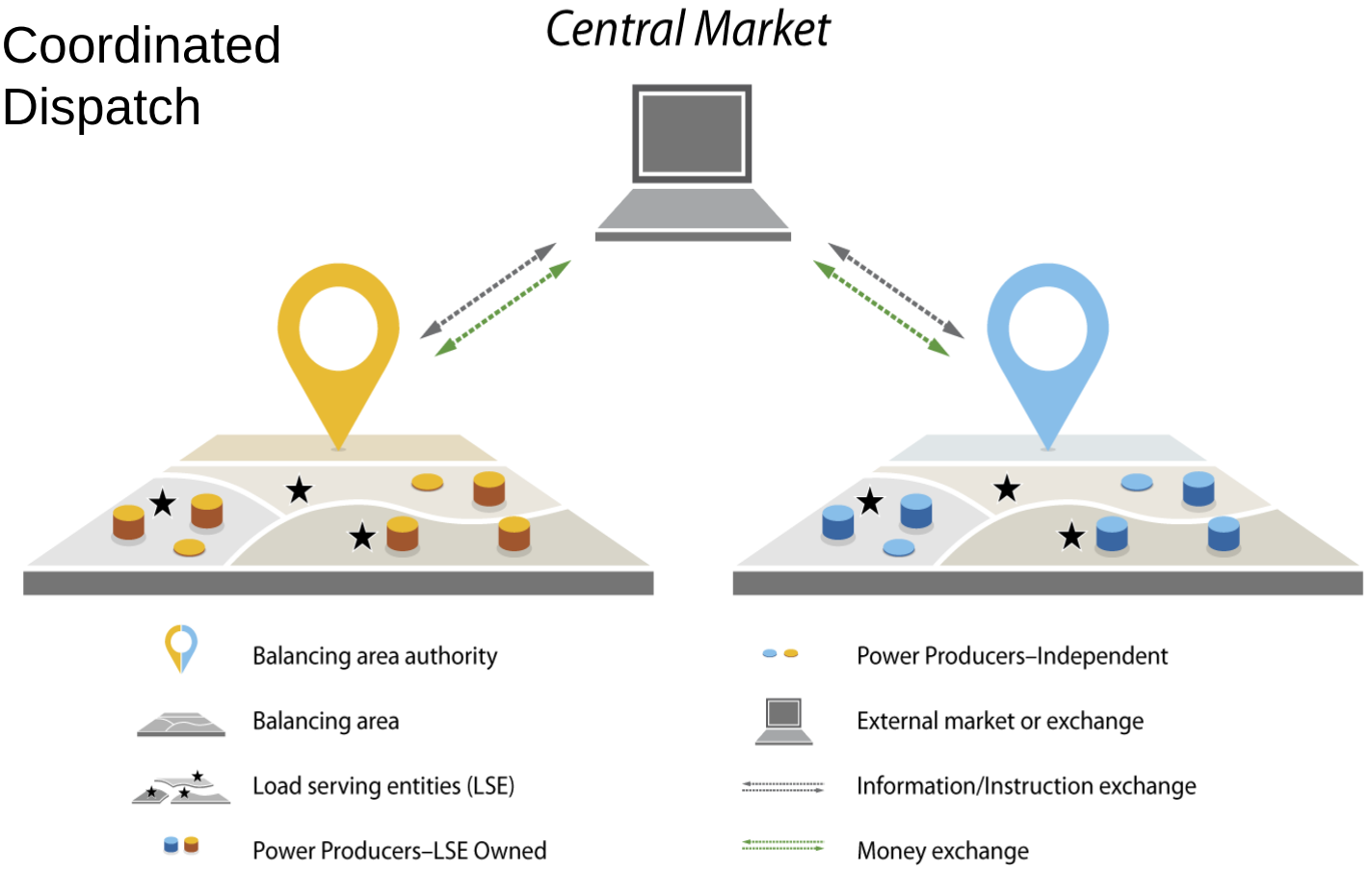
- Sharing reserves between balancing areas means each balancing area can maintain less reserve capacity, lowering costs.



Balancing area coordination: coordinated dispatch

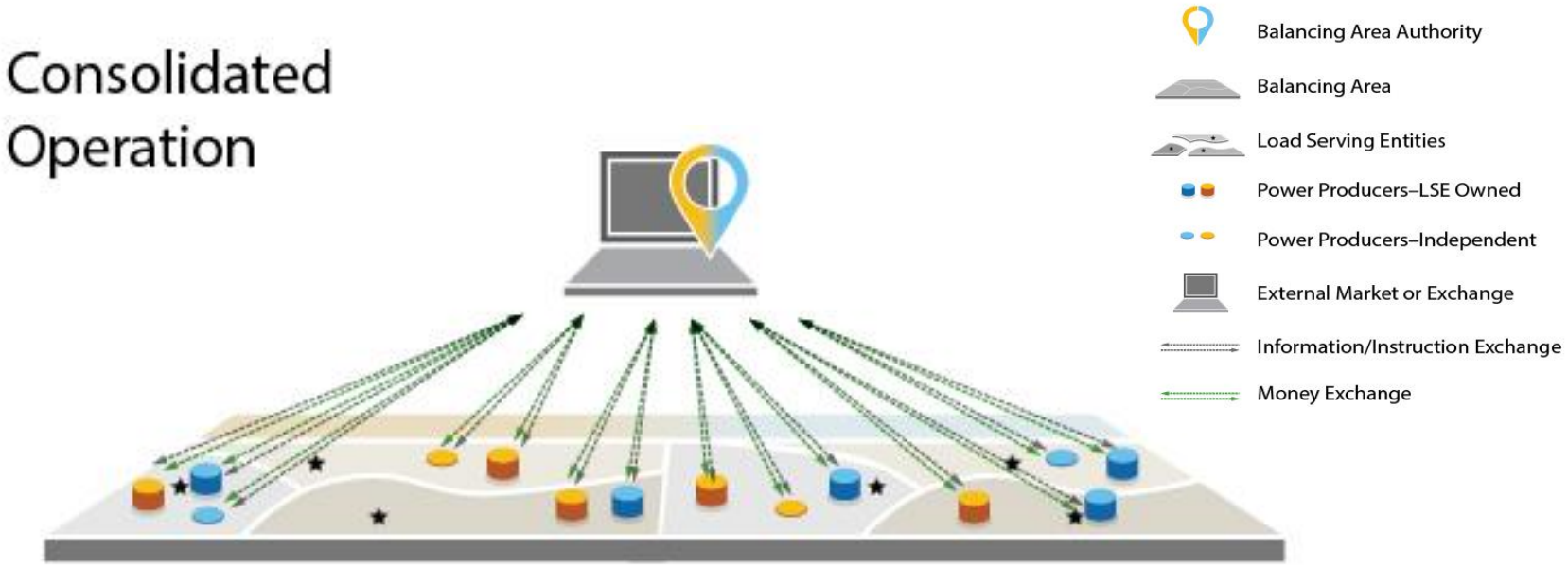
Example: Energy Imbalance Market

Coordinated Dispatch



Balancing area coordination: consolidated operations

- Consolidated operations involves merging of two or more balancing authorities into a single entity



Fully captures the benefits of geographic diversity in demand, wind, solar, and provides more accurate dispatch

Where are we?

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Pathways to achieving “big and fast”

NON-MARKET MECHANISMS

Flexibility mechanisms

Non-market Mechanisms

Big

- Expand balancing footprints and consider geographic diversity
- Coordinate dispatch with neighboring balancing areas
- Coordinate unit commitment with neighboring balancing areas
- Merge business practices with neighbors: consolidated operations

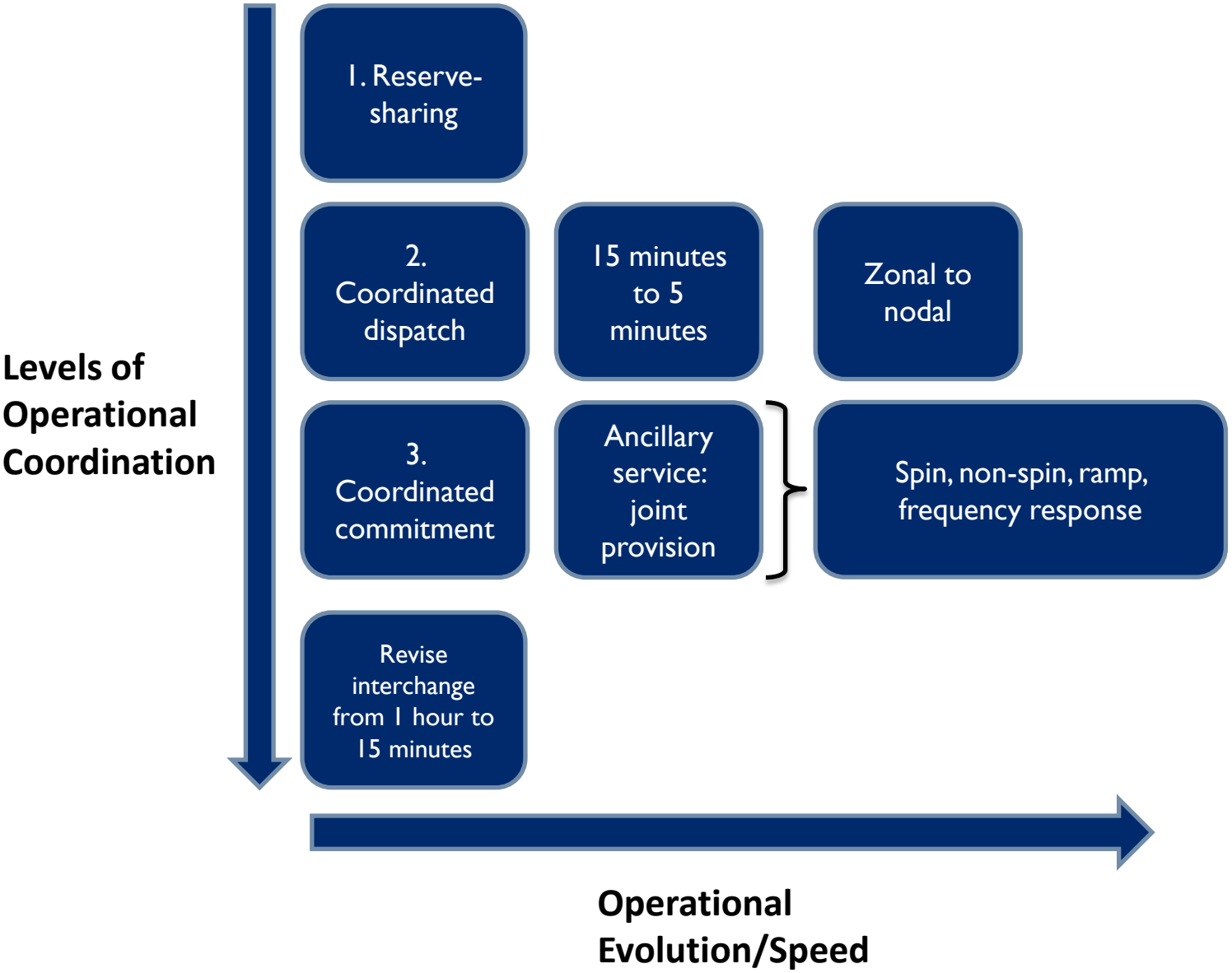
Fast

- Economic dispatch at 5-minute time steps
- Sub-hourly (e.g., 15-minute) interchange schedules
- Revise contracts to value flexibility, such as fast changes to purchased generator output

These mechanisms do not require a market

Pathways to achieve "big" and "fast"

Non-market Mechanisms



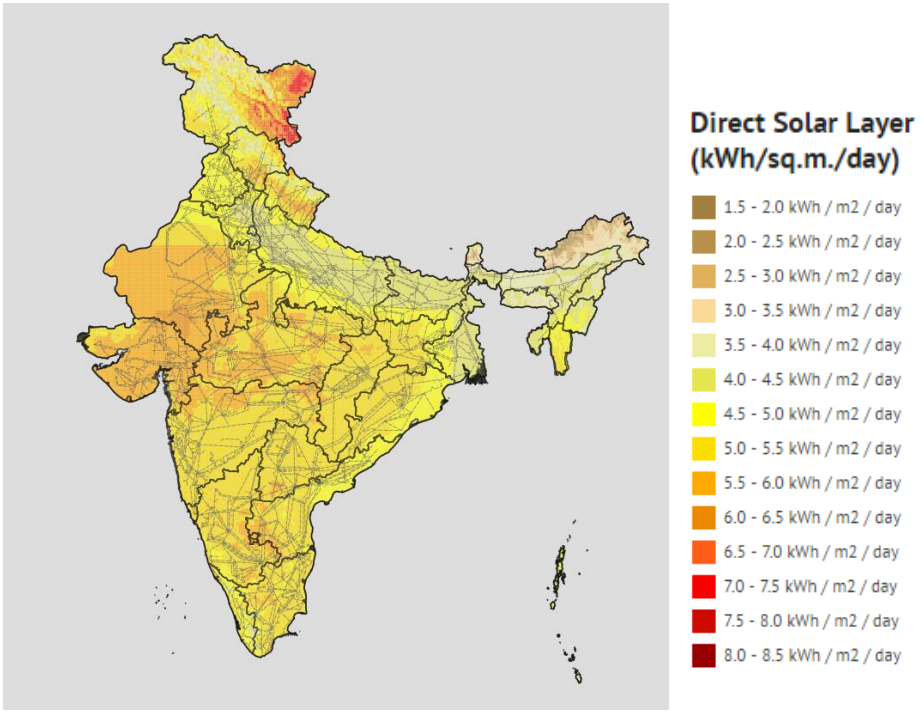
Case study: India

Non-market Mechanisms

India has moved towards big and fast system operations

- Synchronized national grid in 2013
- Modified the dispatch time block from one hour to 15-minutes in 2012
  - More gradual ramping and smoother morning and evening peaks
- Future: improved coordination among state balancing areas?

Solar irradiance and transmission lines in India



Source: NREL

Pathways to achieving “big and fast”

MARKET MECHANISMS

Big and Fast: Mechanisms for Flexibility

Market Mechanisms

Big

- Increase balancing area footprint
- Increase market participation from generation currently self-scheduled
- Coordinate with neighbors
  - Reserve sharing
  - Energy imbalance market (EIM)
  - Consolidated market operations

Fast

- Faster dispatch
- Faster interchange
- Shorter gate closure
- Rolling unit commitment

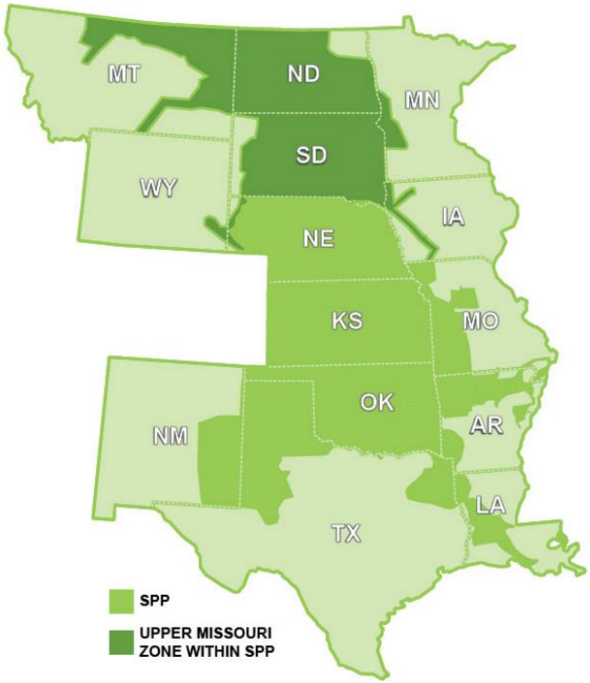
Why start with an Energy Imbalance Market?

An Energy Imbalance Market (EIM) pools electricity generation within a region to balance the variability of electricity demand and renewable energy resources

- EIM is coordinated dispatch
- EIM does not address any type of coordinated unit commitment
- Relatively “easy” step towards more coordination
- Does not require any ancillary services, day-ahead, or other market

Case Study: Southwest Power Pool

Experience from the U.S.
Southwest Power Pool (SPP)

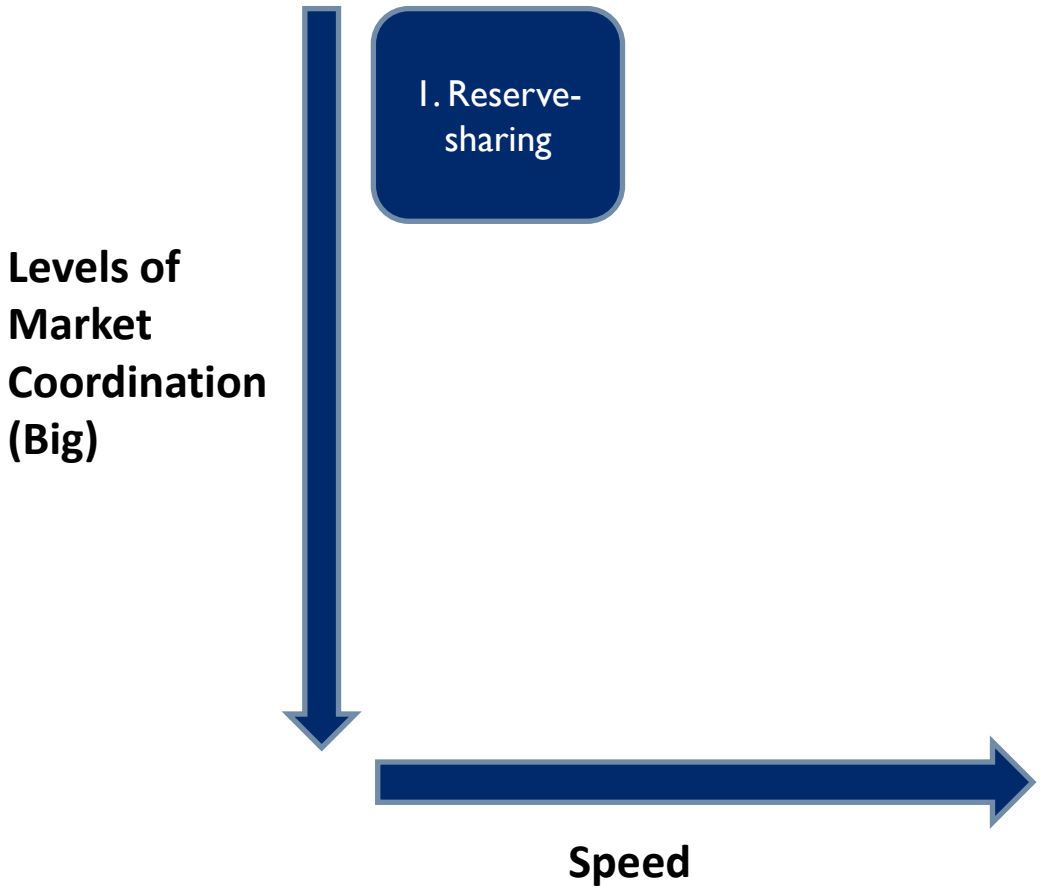


Source: www.basinelectric.com

Reserve sharing → Energy Imbalance Service (EIS) → Consolidated market operations

Case study: Southwest Power Pool

Market Mechanisms



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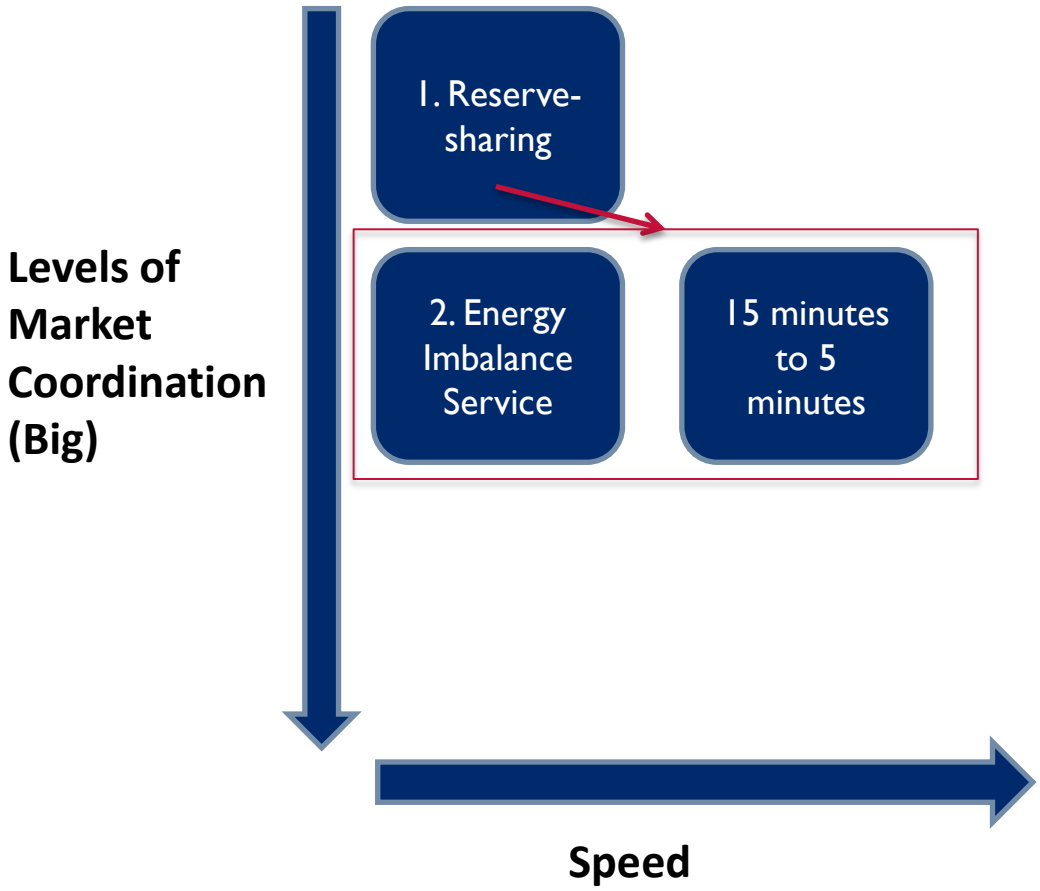

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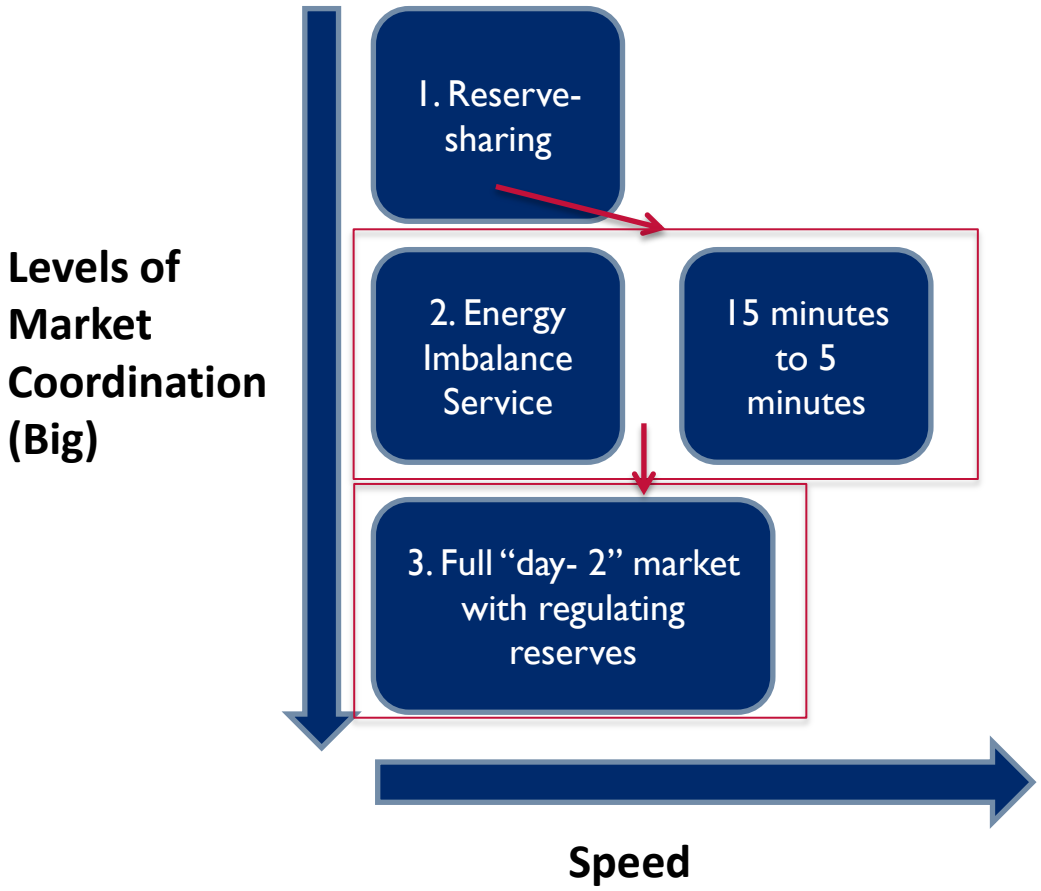

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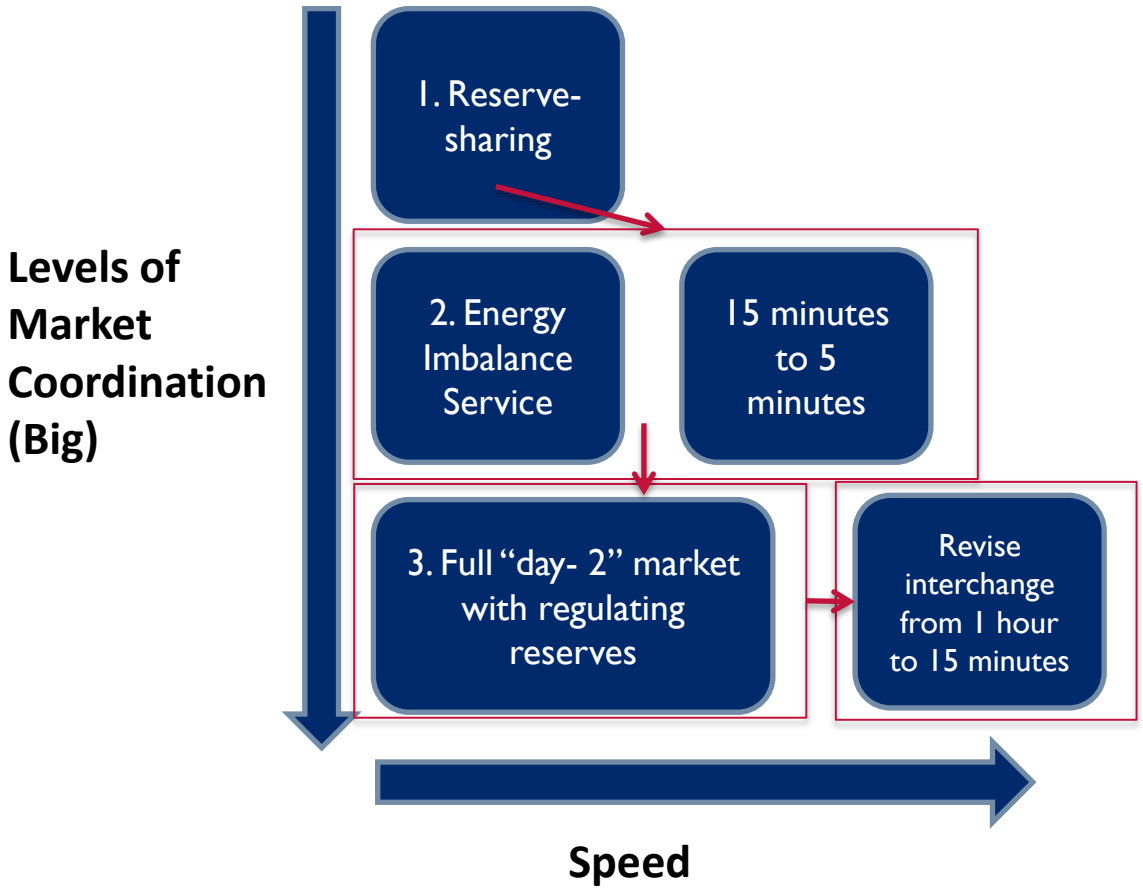


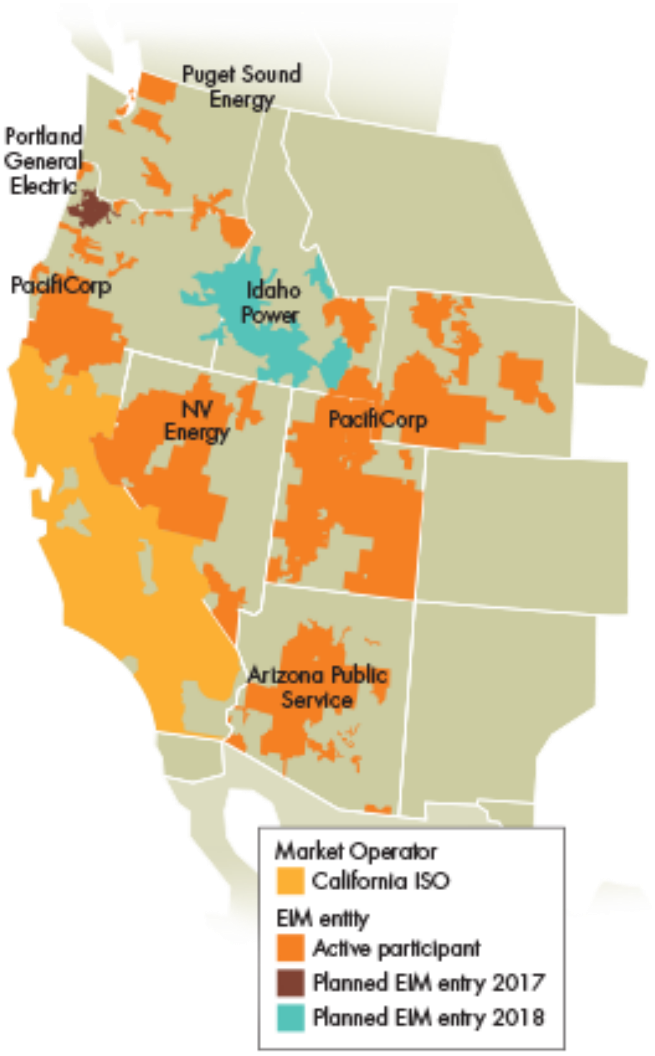
Pathways to achieving “big and fast”

NON-MARKET TO MARKET TRANSITIONS AND HYBRID SYSTEMS

Case Study: Energy Imbalance Market in the Western U.S.

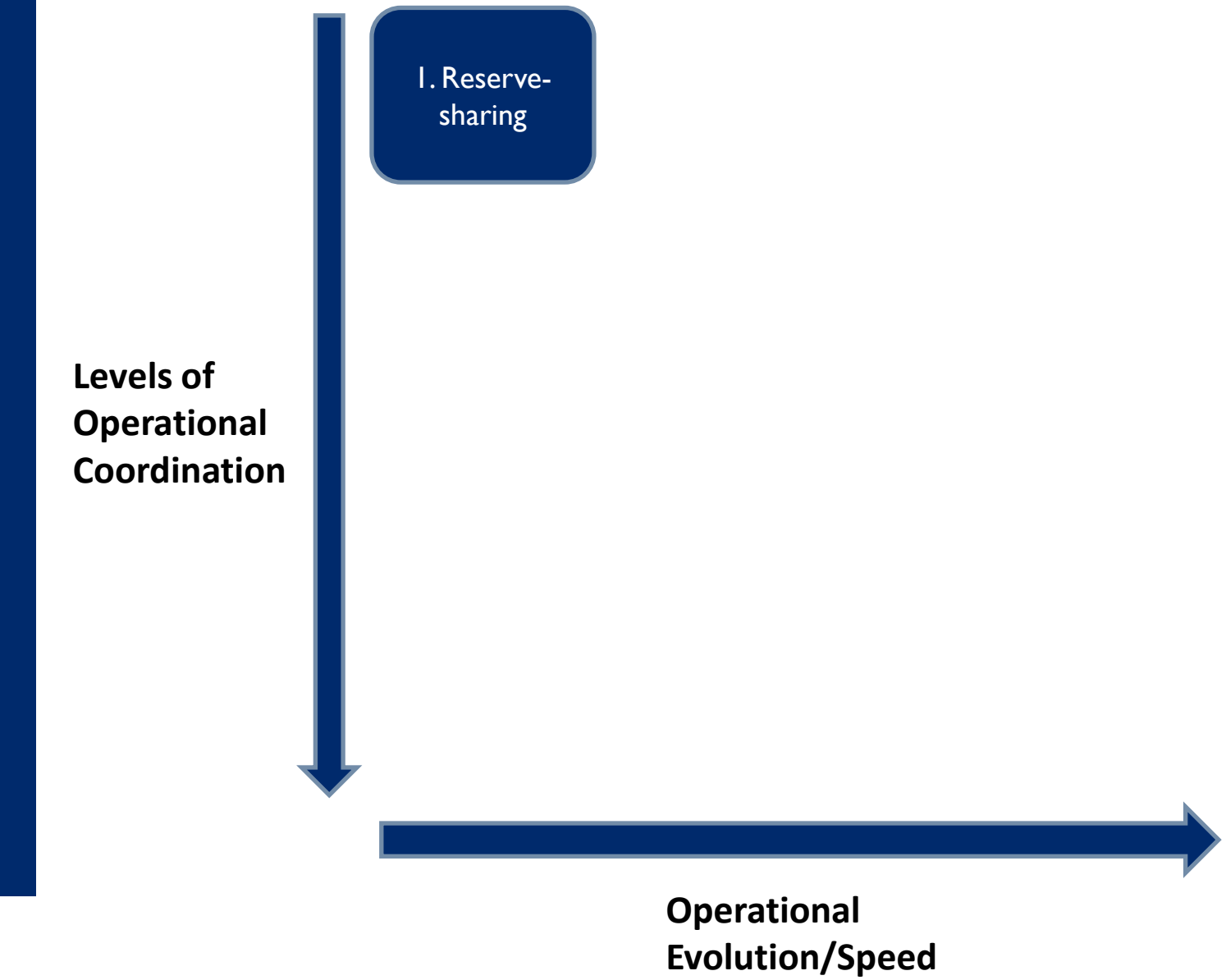
Non-Market to Market and Hybrid

- Modeled after SPP EIS
- EIM could potentially cover all of Western Interconnection
- Initial reluctance, but market is underway
- Market is gradually expanding



Example: Mountain West Transmission Group considering formation of an RTO

Non-Market to Market and Hybrid



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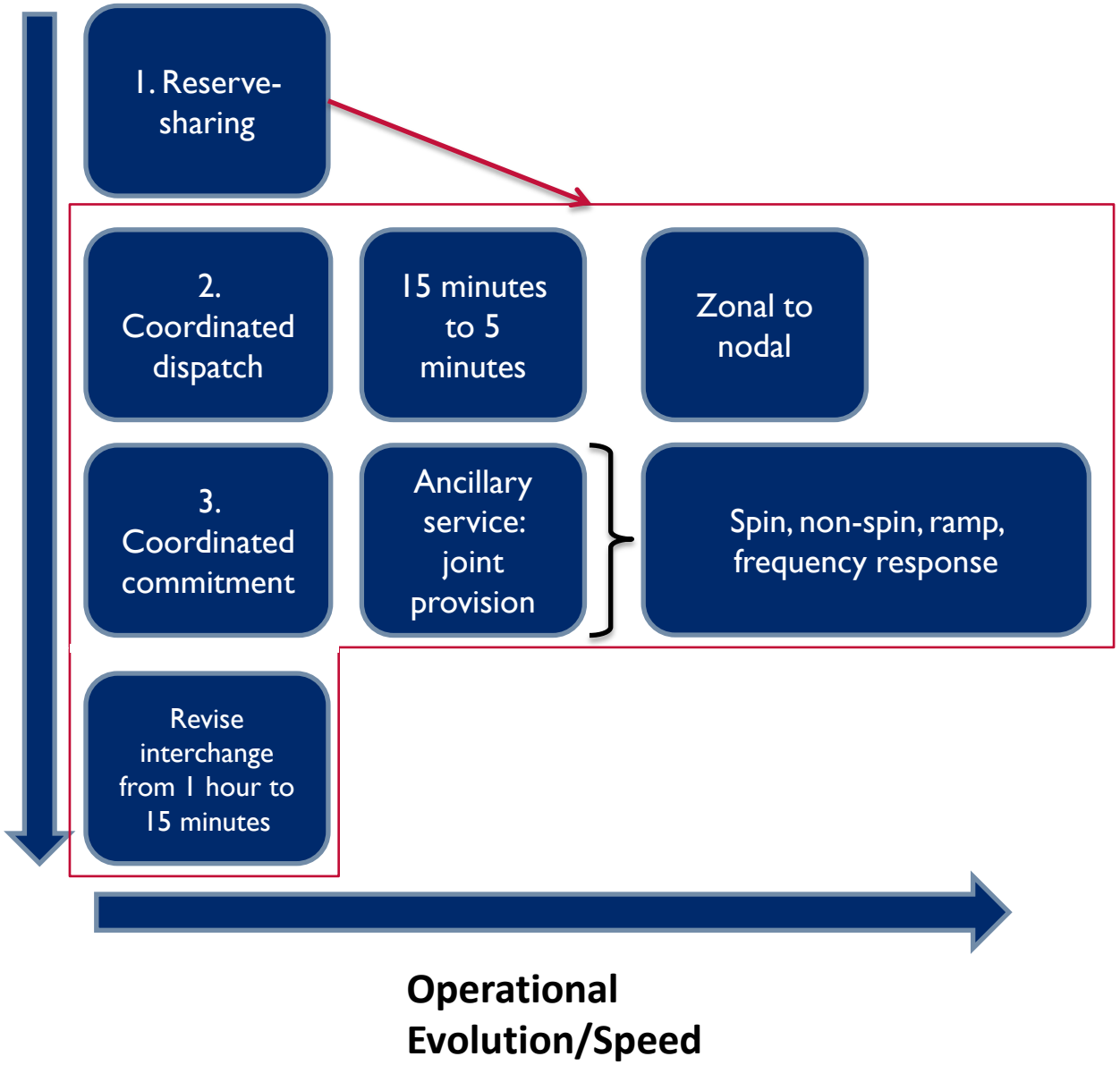
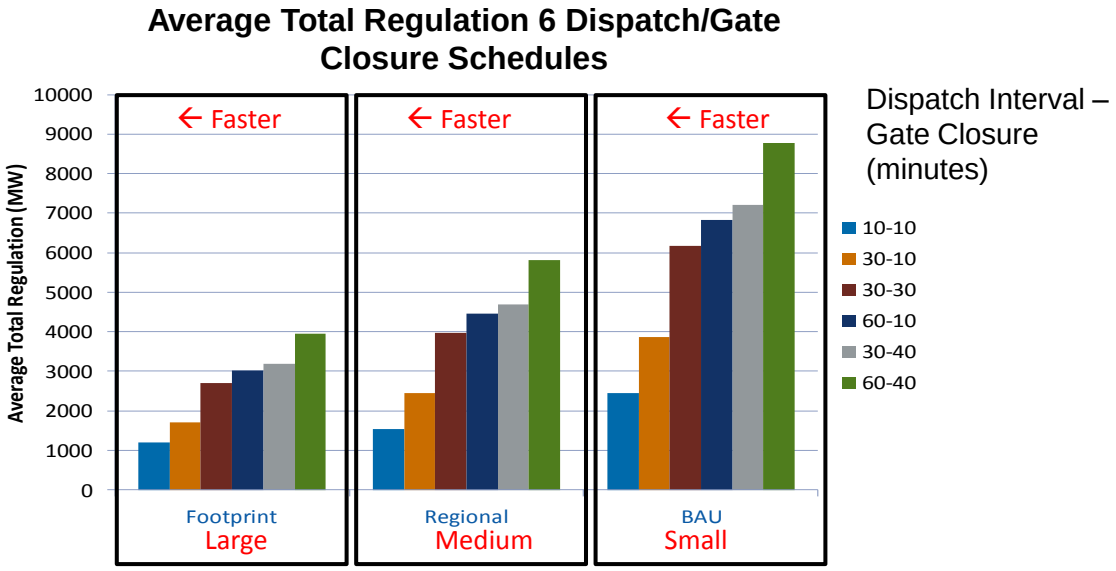


Takeaways

Moving to a large balancing footprint with faster gate closure and dispatch is the key to efficient integration of variable wind and solar energy



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This principle applies to market and non-market areas.

A market is not necessary to have larger balancing footprints and to dispatch more frequently.

Contacts and Additional Information

Webinar Panel

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Greening the Grid

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References and further reading

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