Integrated System Planning:
A Regulator's Perspective

December 3, 2018

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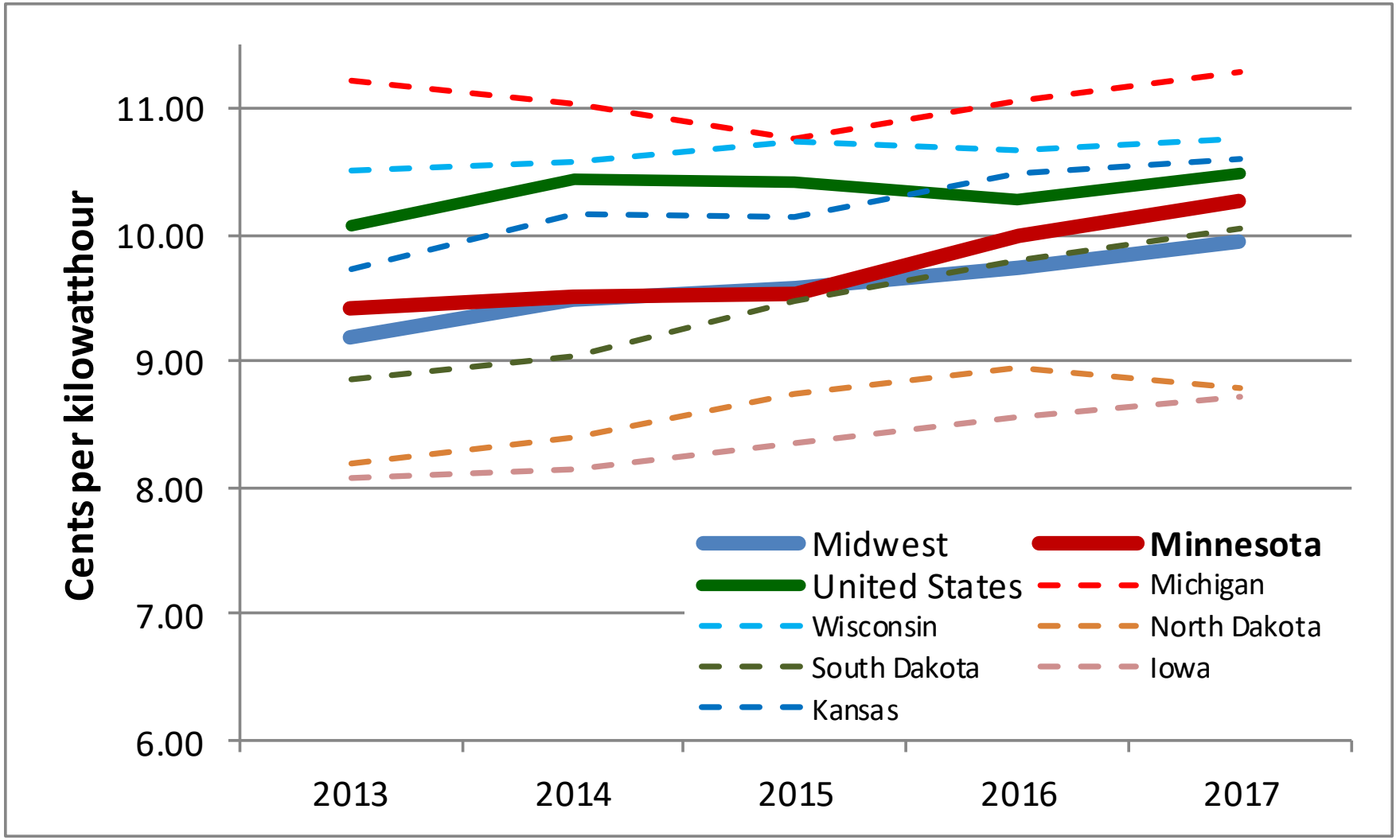
MINNESOTA
PUBLIC UTILITIES COMMISSION

Topics

- Rates & Costs, Transition to Date, Challenges Ahead
- Renewables Integration – Regional Grid & Markets
- Emerging Issues – Grid Services, Flexibility, Electrification
- Modernization – Distribution Grid & Retail Rates
- Looking Forward – Planning for an Integrated Grid

Competitive Electricity Rates

Average Retail Price

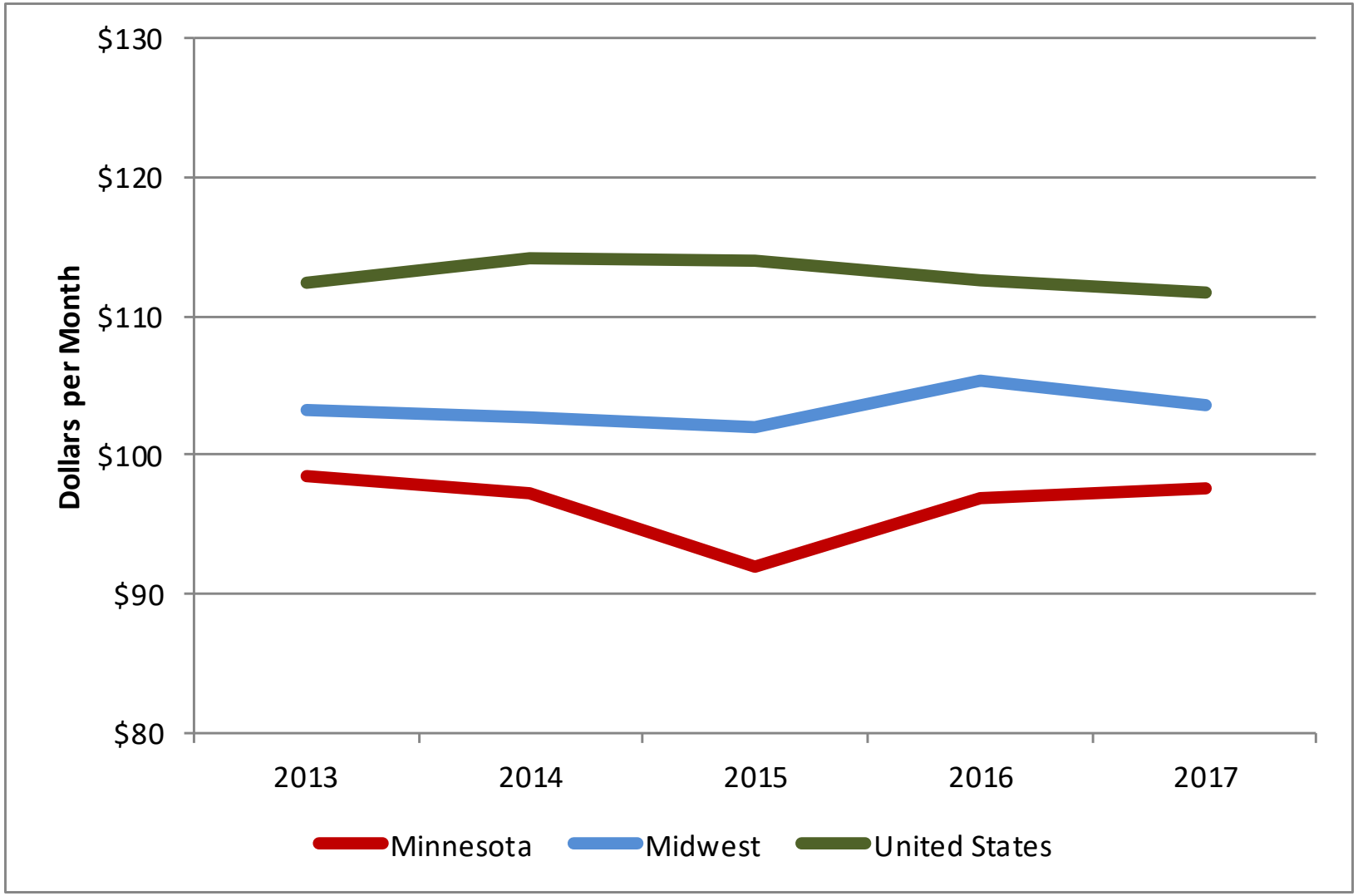


Source: U.S. Energy Information Administration, EIA-861, 10/12/18

Average price of electricity to consumers is a weighted average of total consumer revenue (energy, demand, fuel adj., riders, etc) and total sales across all sectors.

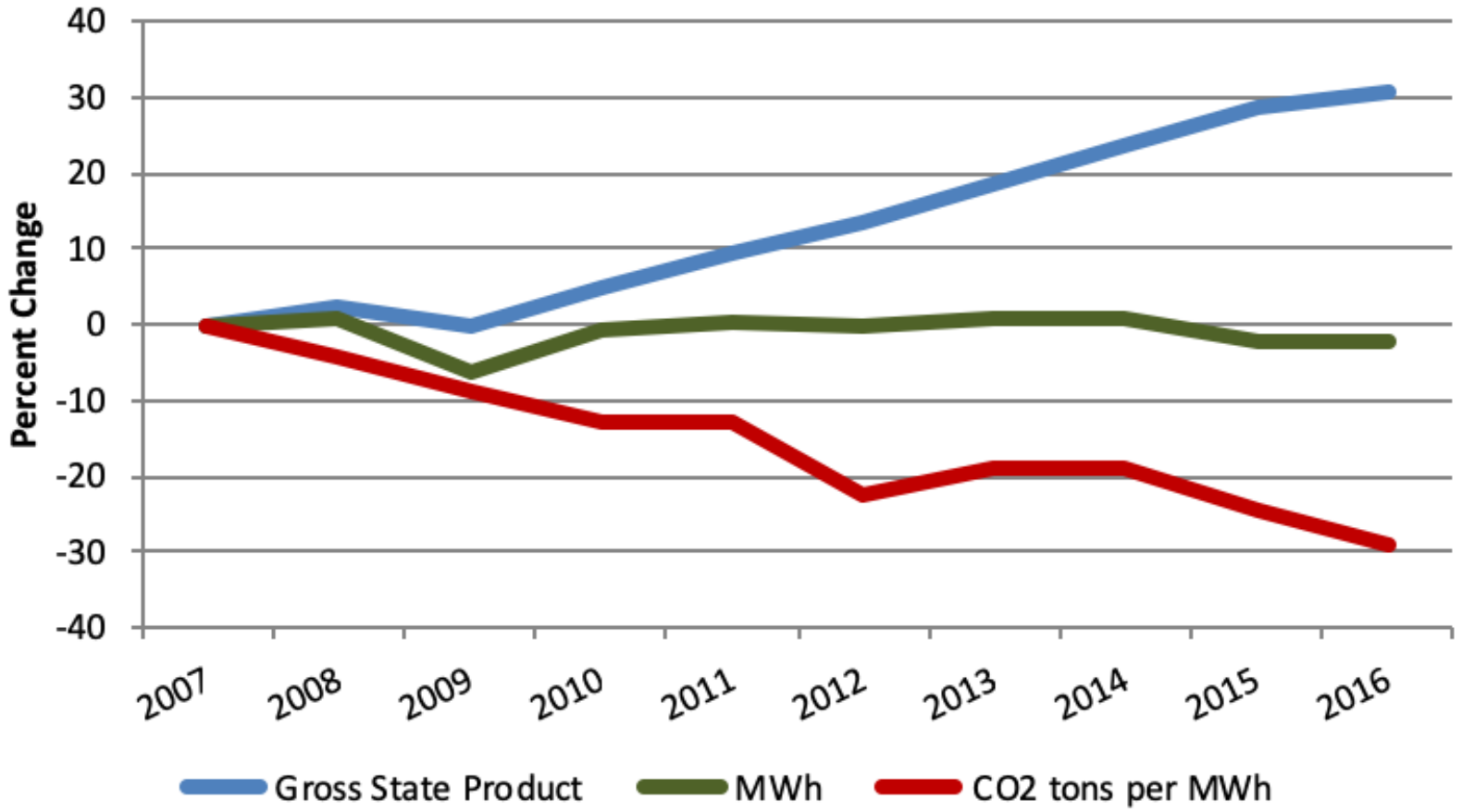
Affordable Electricity Costs

Average Residential Monthly Bill



Source: U.S. Energy Information Administration, EIA-861

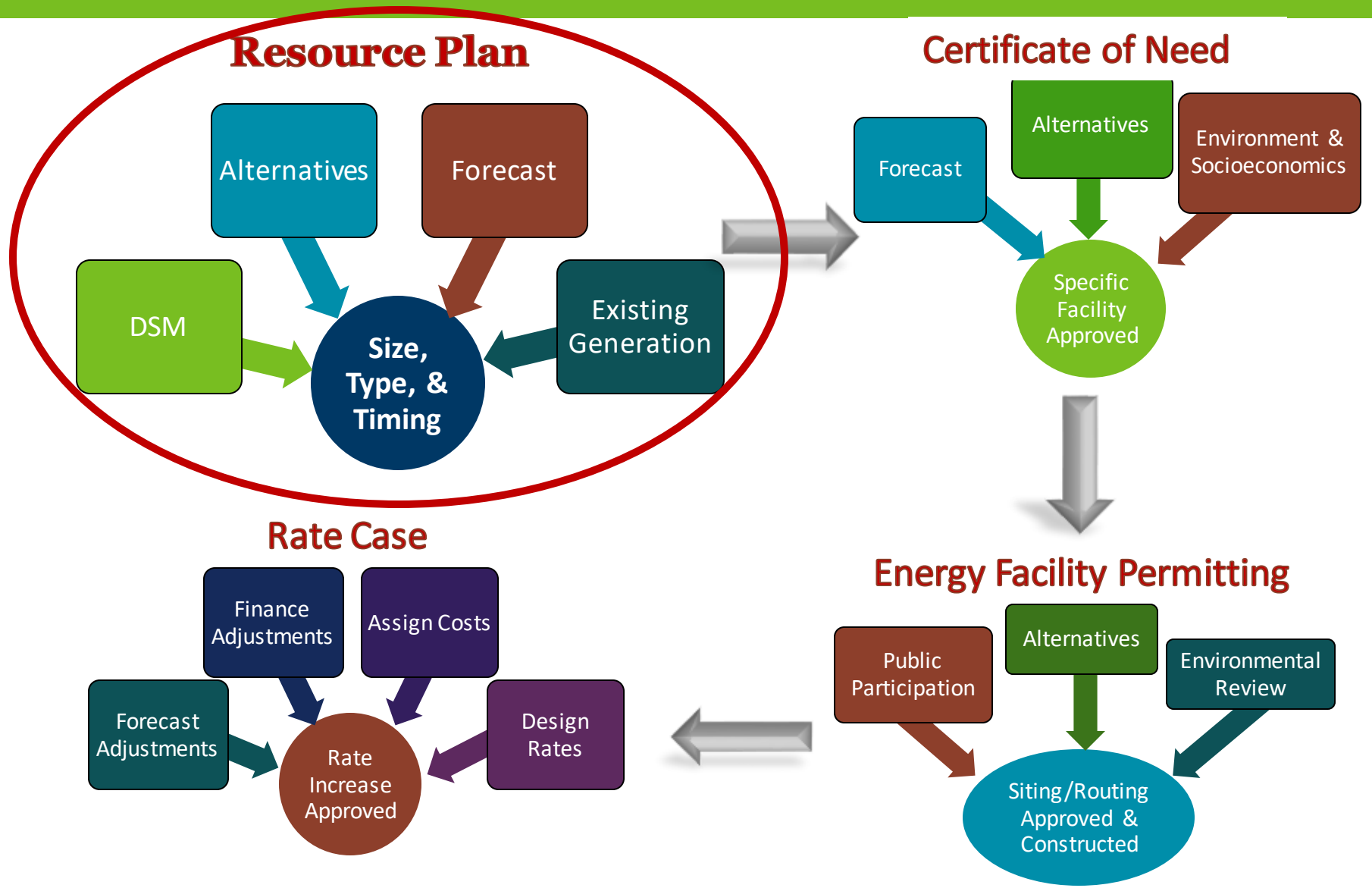
Trends in MN Economic Growth, Electricity Use, and Emissions



Sources: U.S. Energy Information Administration
U.S. Bureau of Economic Analysis

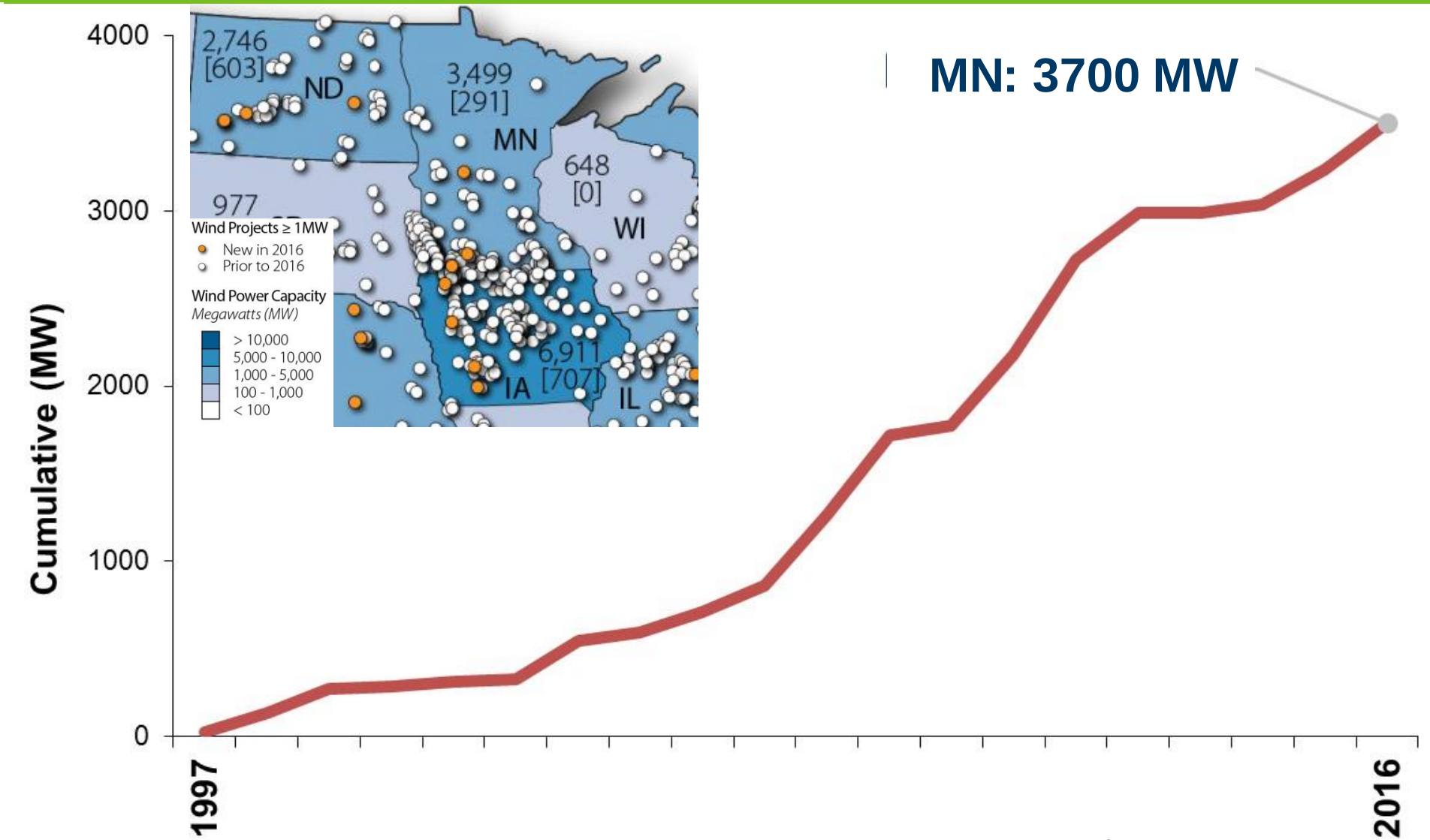
Integrated Resource Planning

Framework to Date



MN Wind Capacity

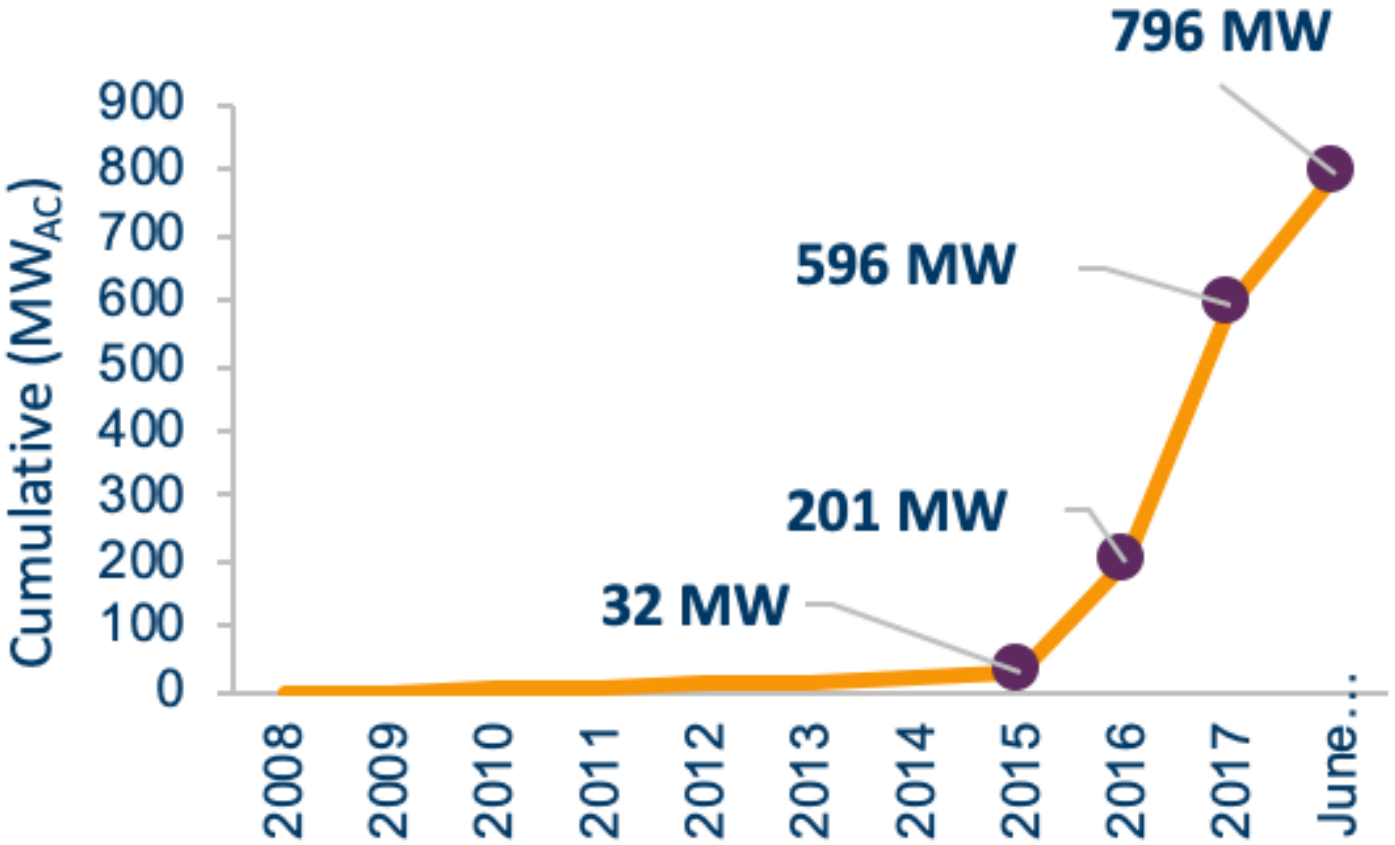
as of September 2018



Source: MN Department of Commerce

MN Solar Capacity

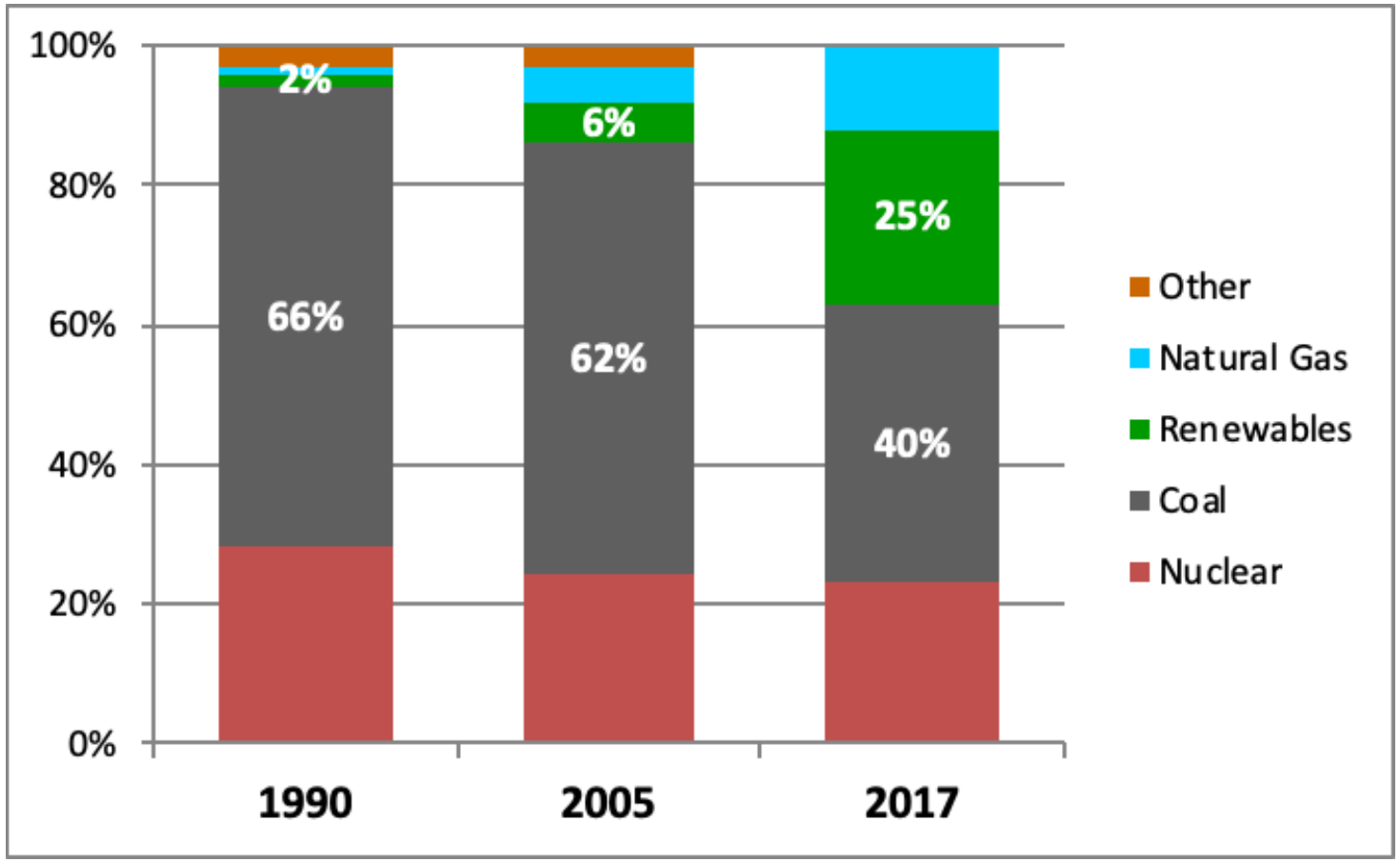
as of September 2018



Source: MN Department of Commerce

Minnesota Generation Fleet Transition

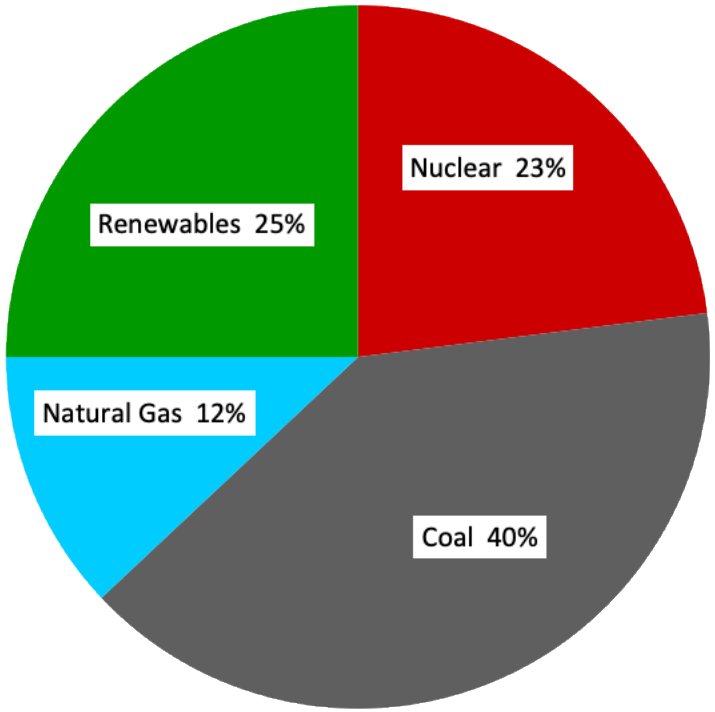
Experience to date: 1990 - 2017



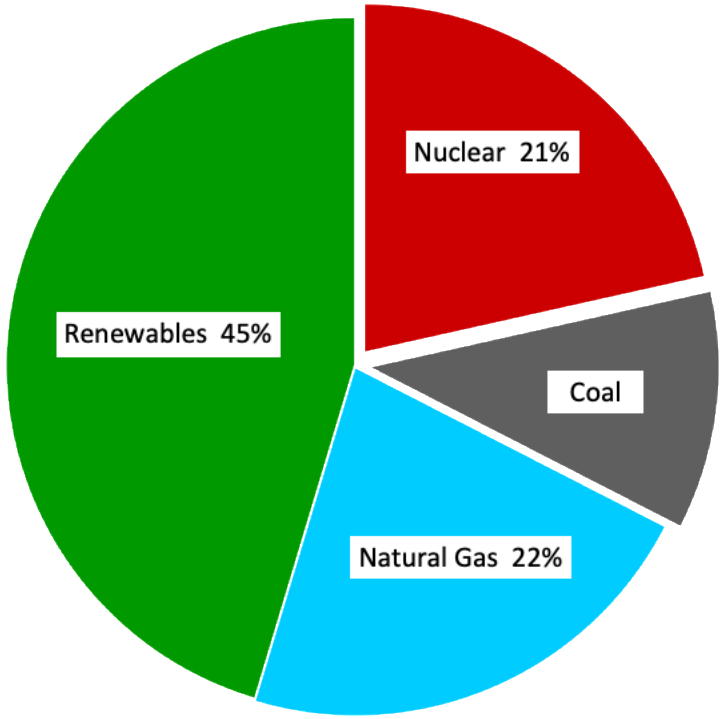
Minnesota Electricity in Transition

Current Plans: 2017 - 2030

2017



2030*



* New natural gas plants added (3 intermediate combined cycle plants and 2 peaking combustion turbines) and new renewables added, per MN IOU IRPs & announcements.

Minnesota Generation Fleet Transition

Upcoming: 2020 - 2040

		Power Plant	Commercial Operation	**Capacity (MW)**	**Announced Retirement or End of Economic Life**	
MN Power	Coal	Boswell 1 & 2	1960	**130**	**2018**	Retirement
Otter Tail	Coal	Hoot Lake 2 & 3	1959, 1964	**140**	**2021**	Retirement
Xcel Energy	Coal	Sherco 1 & 2	1976, 1977	**1360**	**2026, 2023**	Retirement
Xcel Energy	Nuclear	Monticello	1971	**670**	**2030**	Operating license
Xcel Energy	Nuclear	Prairie Island 1 & 2	1973, 1974	**1100**	**2033, 2034**	Operating license
Xcel Energy	Coal	Sherco 3	1987	**860**	**2034**	Economic life
MN Power	Coal	Boswell 3 & 4	1973, 1980	**940**	**2035, 2036**	Economic life
Xcel Energy	Coal	Allen S. King	1968	**510**	**2037**	Economic life

Integration of Variable Renewables
Minnesota Experience

Grid integration of large amounts of wind generation the upper Midwest began in the early 2000s:

- **Several Minnesota-centric *grid integration* studies (2001, 2004, 2006, 2009, 2014), focused on operating reliably and economically with large amounts of variable renewables**

Study methods/models and depth of collaboration evolved as understanding of challenges developed.

Today, the regional grid is planned and operated differently; new approaches and tools; improved market rules.

Integration of Variable Renewables
Lessons Learned

Reducing Wind and Solar integration impacts

- Large, liquid, fast markets;
- Large balancing area with a strong grid; and
- Forecasting wind generation day-ahead

Midwest experience integrating wind

- Variability is mitigated by geographic diversity;
- Wind contributes to resource adequacy;
- Market rules have evolved to require fuller wind participation.

Wind and solar generators are power plants

- Are Dispatched; Ride through disturbances; Provide reactive power; Capable of fast and accurate ramping and active power control.

Essential Reliability Services (NERC)

The changing resource mix motivates us to evolve our planning:

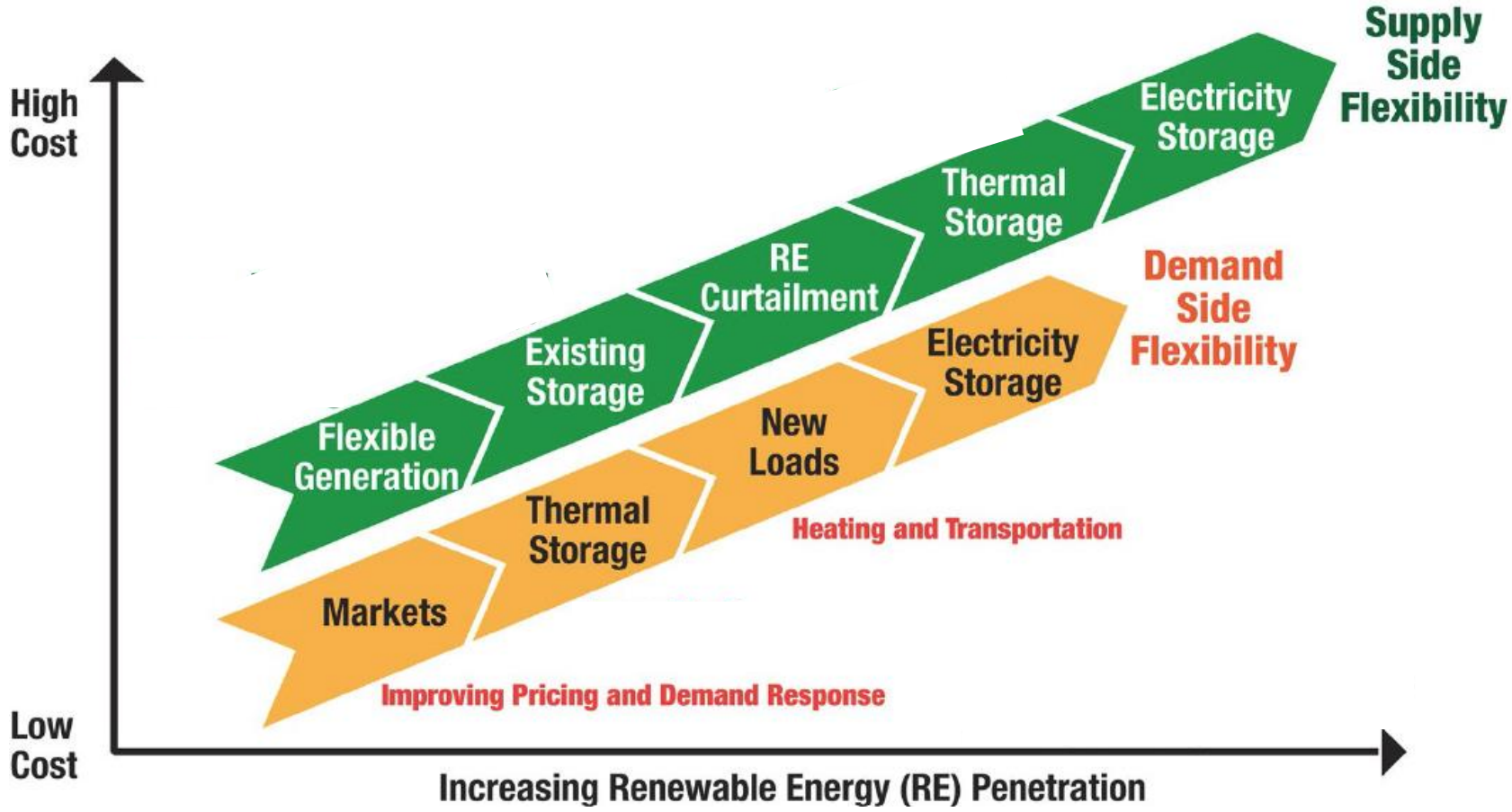
- Less coal, more renewables, more demand response, more gas;
- How will this affect grid attributes that we don't explicitly plan for today?

Core grid services include:

- Voltage control;
- Frequency support;
- Ramping capability.

These essential reliability services can and increasingly will come from a range of resources.

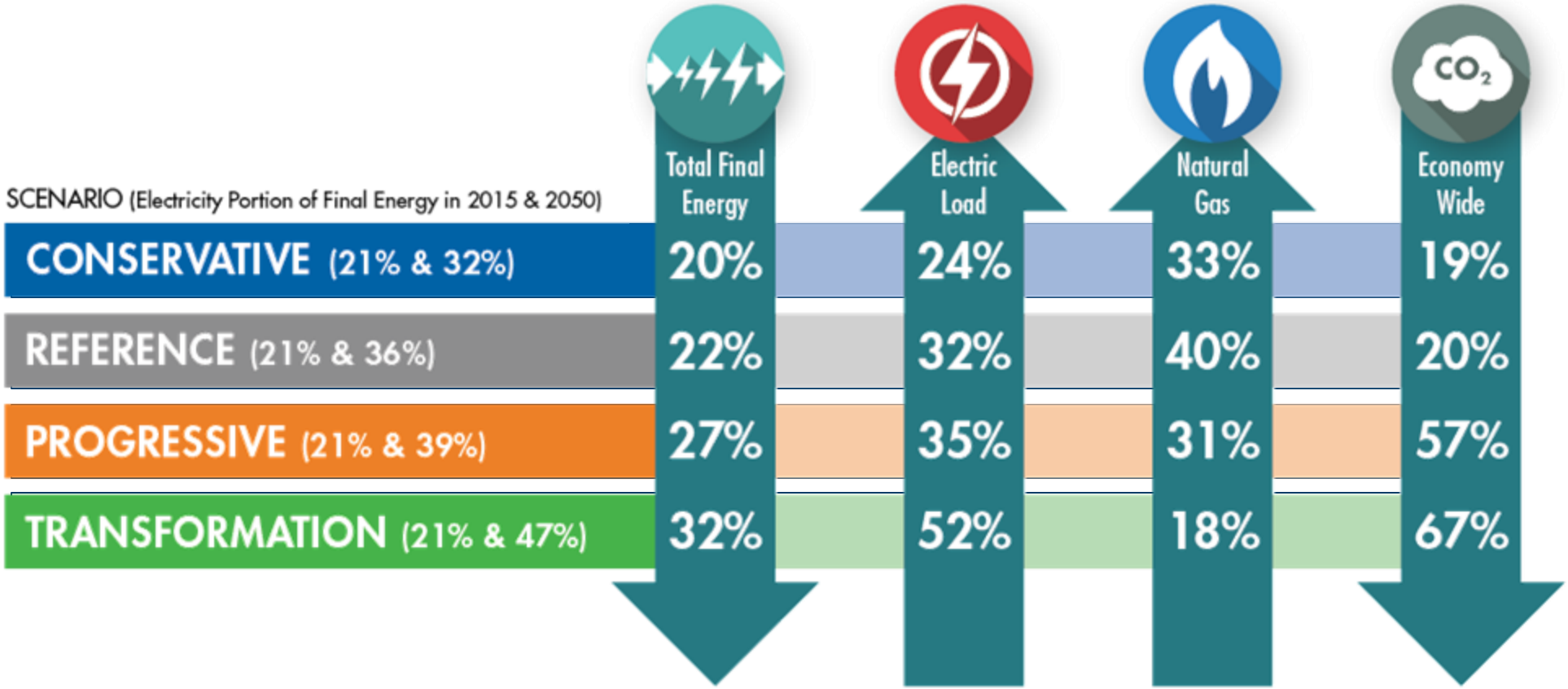
Flexibility Supply Curve



Flexible load as a resource *and* the robust regional grid & markets are key to enabling the evolving resource mix.

Source: NREL, "The Role of Energy Storage with Renewable Electricity Generation", Paul Denholm et al., January 2010

U.S. National Electrification Assessment – 2015 to 2050



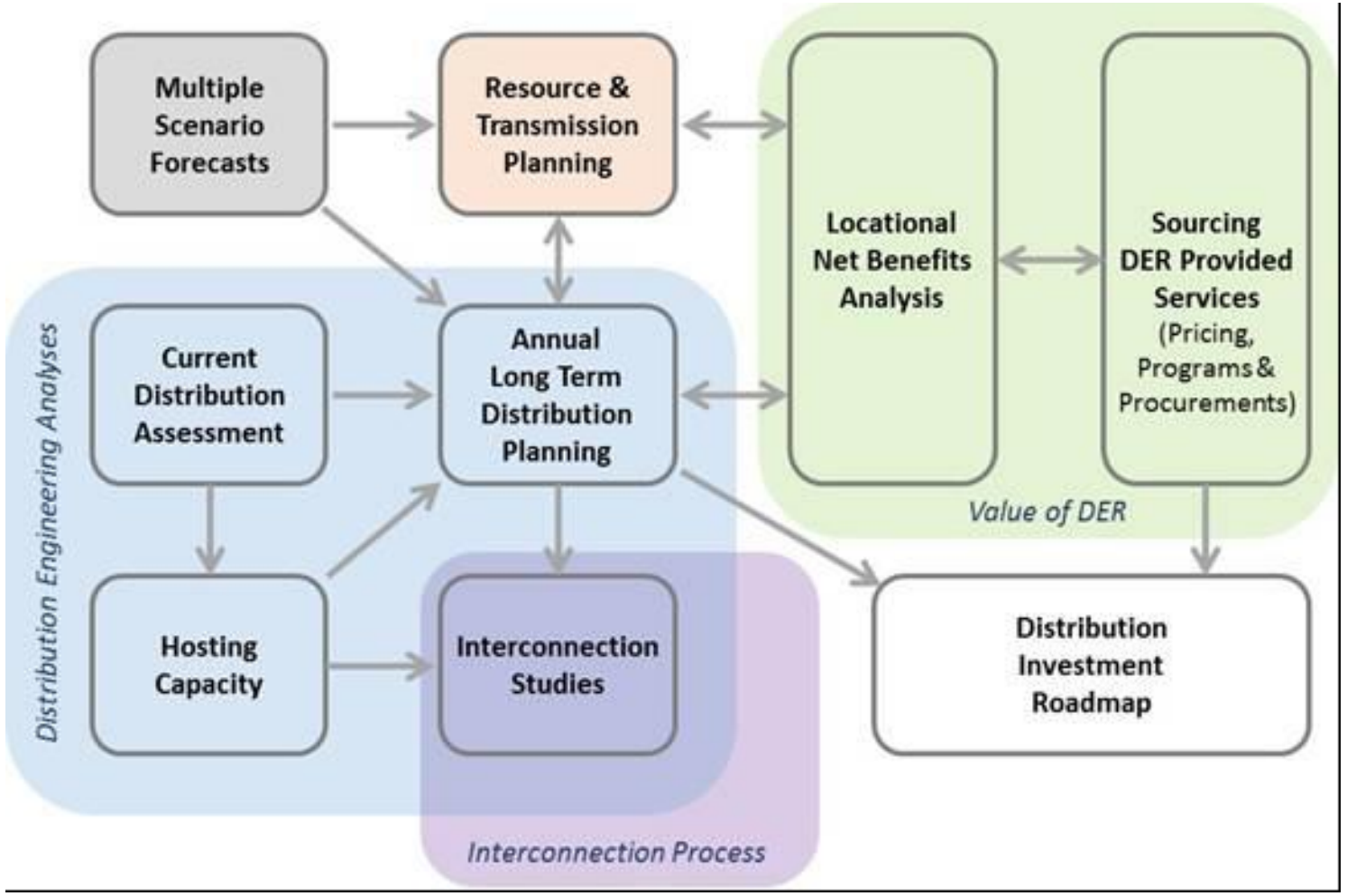
For more information on EPRI's Efficient Electrification Initiative:
https://www.epri.com/#/pages/sa/efficientelectrification

EPRI | ELECTRIC POWER RESEARCH INSTITUTE

MN Grid Modernization

- *Maintain and enhance* the **safety, security, reliability, and resilience** of the electricity grid, **at fair and reasonable costs, consistent with the state's energy policies**;
- *Enable* **greater customer engagement, empowerment, and options** for energy services;
- Move toward the creation of **efficient, cost-effective, accessible grid platforms for new products, new services**, and opportunities for adoption of new distributed technologies;
- *Ensure* **optimized utilization of electricity grid assets and resources** to minimize total system costs;
- *Facilitate* **comprehensive, coordinated, transparent, integrated distribution system planning**.

Integrated Distribution Planning



Source: De Martini - ICF, *Integrated Distribution Planning,* August 2016. Prepared for the Minnesota PUC.

MN PUC Modernization Dockets

Interconnection Standards	• Interconnection Process (2018) • Technical Standards (2019)
Distribution Grid	• Distribution Planning (2018) • Grid Upgrades - AMI/ADMS
Rate Design	• TOU/Critical Peak Pricing • EV Infrastructure and Rates
Performance Considerations	• Xcel Multi-Year Rate Case • Metrics/Incentives

Evolving Electric Grid

The grid is at a time of significant change, as:

- **Large infrastructure ages;**
- **Consumer demands evolve**;
- **New technology costs fall**.

=> **Decarbonization, Decentralization, Digitization**

Tomorrow's *integrated grid* will optimize and extract value *throughout the system*:

- will be **more distributed and flexible;**
- will **operate resiliently**;
- will **be reliable, affordable, and cleaner.**

Distribution will need updated planning & investment;

Regional transmission will continue to be vital; and,

Resource planning must evolve to identify and capture benefits for consumers of an increasingly integrated system.

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Thank you!

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