Economic, Reliability, & Resiliency Benefits of Interregional Transmission Capacity

GE ENERGY CONSULTING

Case study focusing on the Eastern United States in 2035

October 2022

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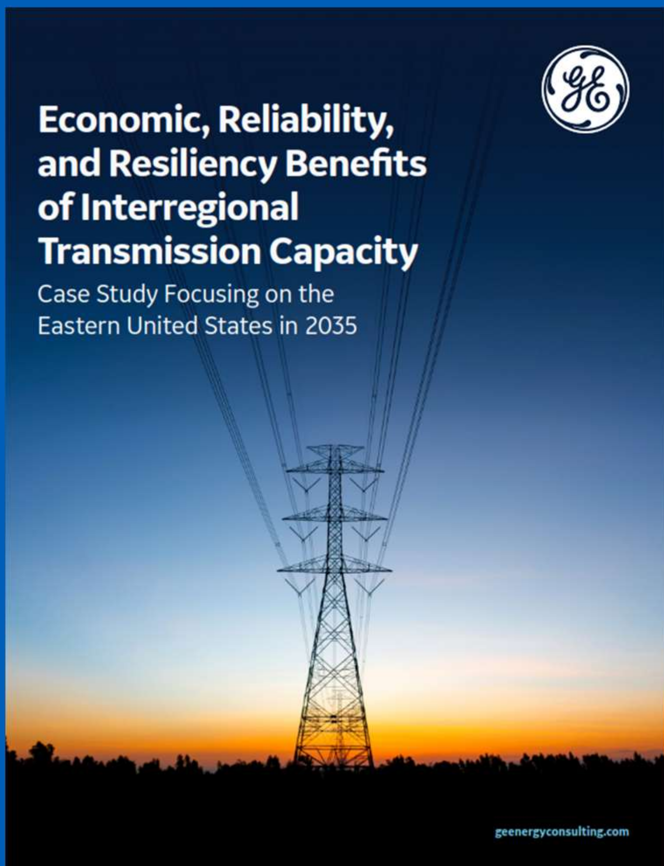

GE Energy Consulting study for the Natural Resources Defense Council (NRDC).

GE Energy Consulting (study team)

- **Project lead:** Sheila Tandon Manz, Ph.D., Technical Director
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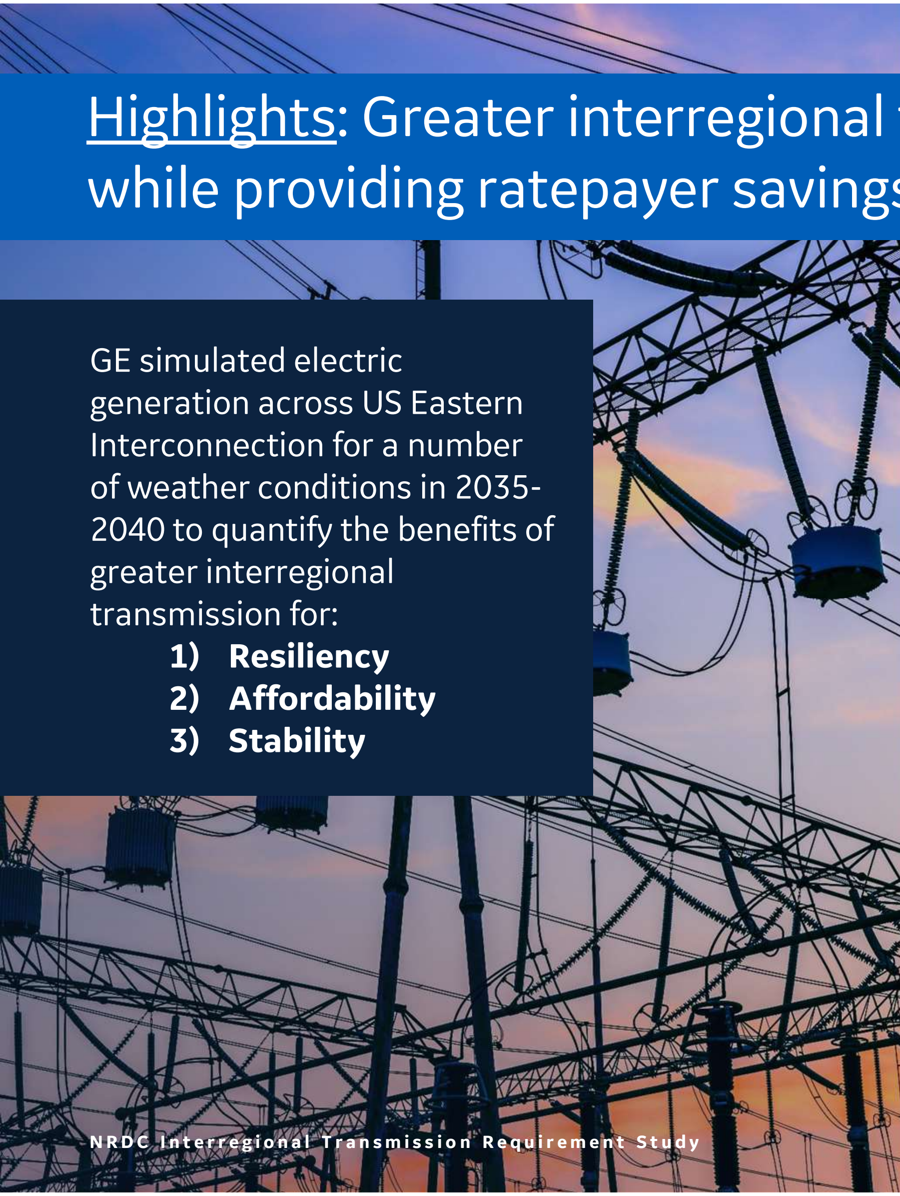
Technical Review Committee

- Debbie Lew, ESIG
- Kevin Porter, Exeter Associates
- Rob Gramlich, Grid Strategies
- Jay Caspary, Grid Strategies
- Ric O'Connell, GridLab

Highlights: Greater interregional transmission helps keep the lights on while providing ratepayer savings



GE simulated electric generation across US Eastern Interconnection for a number of weather conditions in 2035-2040 to quantify the benefits of greater interregional transmission for:

1) **Resiliency**
2) **Affordability**
3) **Stability**

- **HEAT WAVE, AUGUST 2035**: **Greater transmission prevented ~740,000 customers losing power** across New York City and Washington, DC saving $875M
- **POLAR VORTEX, FEBRUARY 2035**: **Greater transmission prevented ~2 million customers losing power** across Boston, New York City, Baltimore and Washington, DC saving $1B
- **NORMAL WEATHER, 2035**: **Greater transmission saved $3B/year in 2035 increasing to $4B in 2040** via greater access to lower cost generation
- Greater transmission **lowered capacity and ancillary service requirements, saving $2B** in 2035
- Example cost benefit analysis shows **$12B in net benefits** from 87GW of incremental interregional transmission

Grid stability is also increasingly a risk during extreme weather events. Alternate interregional transmission technologies (e.g. DC vs AC connections) should be considered to maintain stability especially with high inverter-based resource penetrations.

Interregional transmission expansion can have multiple benefits

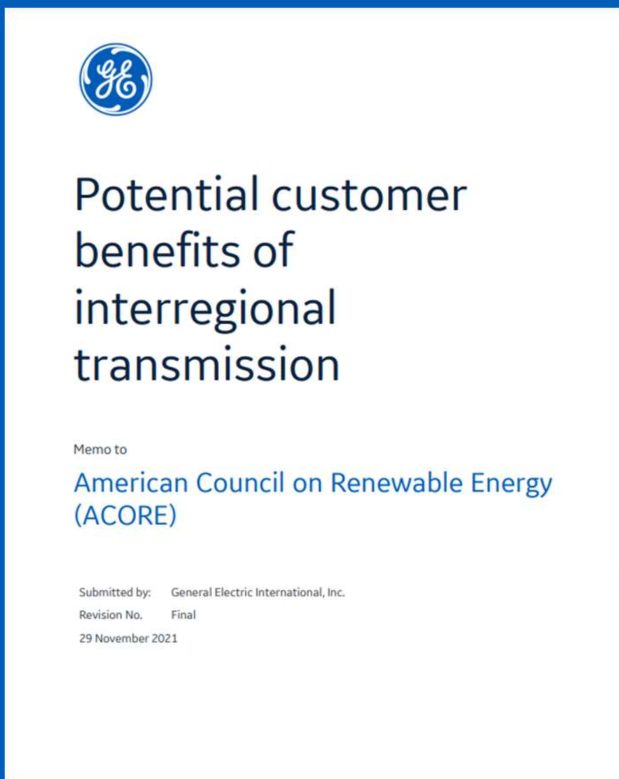
1. **RESILIENCY:** The lights can stay on in the face of greater uncertainty/extreme weather

2. **AFFORDABILITY:** Customers experience lower energy costs via access to lower cost generation

3. **STABILITY:** The lights can stay on as grid technologies diversify

How can FERC determine a minimum interregional transmission requirement?

How can FERC define a minimum interregional transmission requirement?



Potential customer benefits of interregional transmission

Memo to

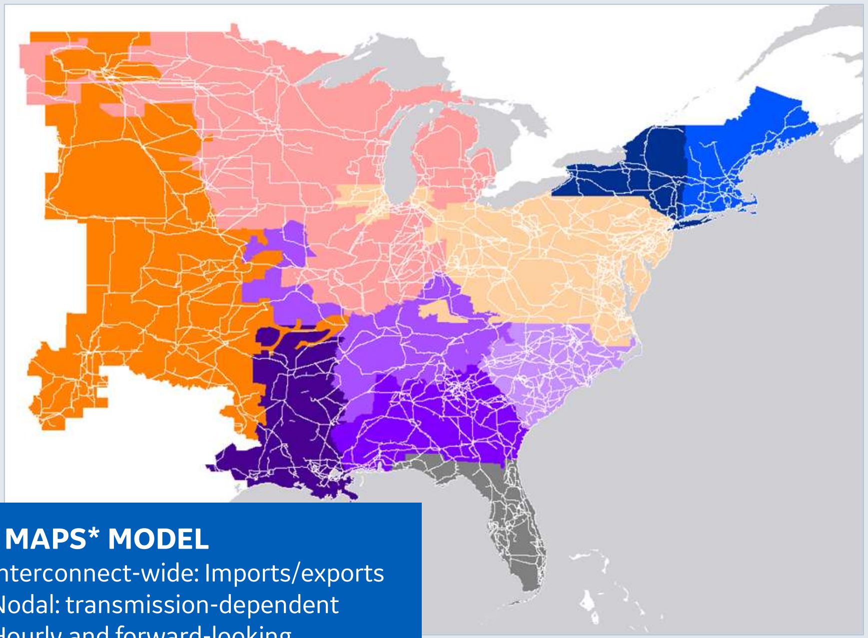
American Council on Renewable Energy (ACORE)

Submitted by: General Electric International, Inc.
Revision No. Final
29 November 2021

- Industry has considered several possible metrics:
  - Flat percentage of load or generation
  - Single largest contingency
- GE published a paper for ACORE suggesting a methodology based on *interregional power flow needs & benefits*
- Current study work focused on simulations illustrating methodology implementation

https://acore.org/wp-content/uploads/2021/12/02-GEEnergyConsulting_ACORE_InterregionalTransmissionMemo_211129.pdf

GE proposed methodology: Simulate system w/constrained & unconstrained transmission to compare benefits & suggest requirement



GE MAPS* MODEL

- ✓ Interconnect-wide: Imports/exports
- ✓ Nodal: transmission-dependent
- ✓ Hourly and forward-looking
- ✓ Supercomputer-enabled

GE simulated the Eastern Interconnection (EI) in GE MAPS*

1. Under two **transmission conditions**
   - **a) Constrained** transmission flows
   - **b) Unconstrained** transmission flows (transmission w/ Canada remains constrained)

Assumes *inter-regional* needs coordinated w/ *intra-regional*

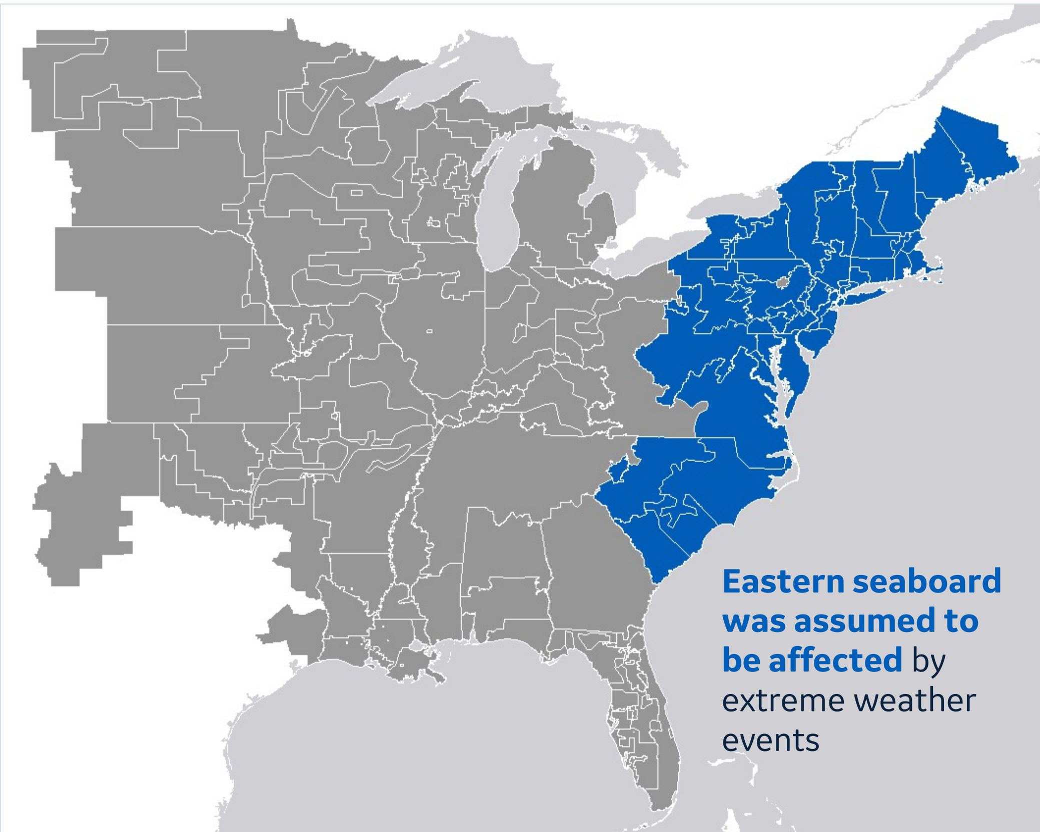
2. For three different **weather conditions**:
   - **a) Heat wave**
   - **b) Polar vortex**

     } Test resiliency benefits
   - **c) Normal** weather: Test affordability benefits

GE also performed an analysis on subset of EI to assess potential stability qualifications

Ref: ABB Hitachi * Trademark of General Electric

GE simulated two extreme weather scenarios



Two extreme weather events were simulated:

1) **Summer Heat Wave:** Load 30% higher due to extreme heat

2) **Winter Polar Vortex:**
   - Load 40% higher due to extreme cold
   - ~15% generation outages due to fuel constraint
   - Gas prices spike to $40/MMBTU due to shortages

Eastern seaboard represents ~35% of total peak load for the Eastern Interconnect.

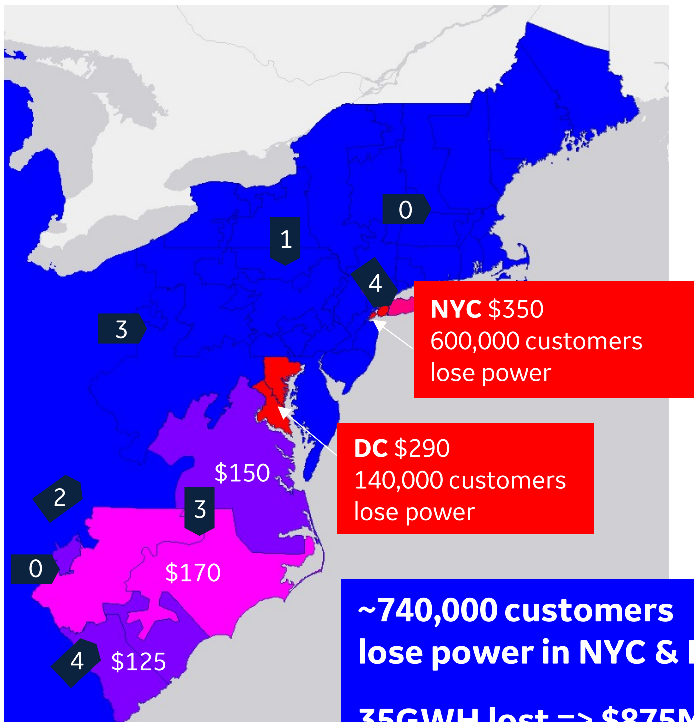
Ref: ABB Hitachi

Heat wave 2035: Unconstraining transmission eliminates load losses

Demand increased 30% due to heat

2035 CONSTRAINED TRANSMISSION

Constrained interregional power flows led to load losses



~740,000 customers lose power in NYC & DC

35GWH lost => $875M
(@$25k/MWH)

$/MWH

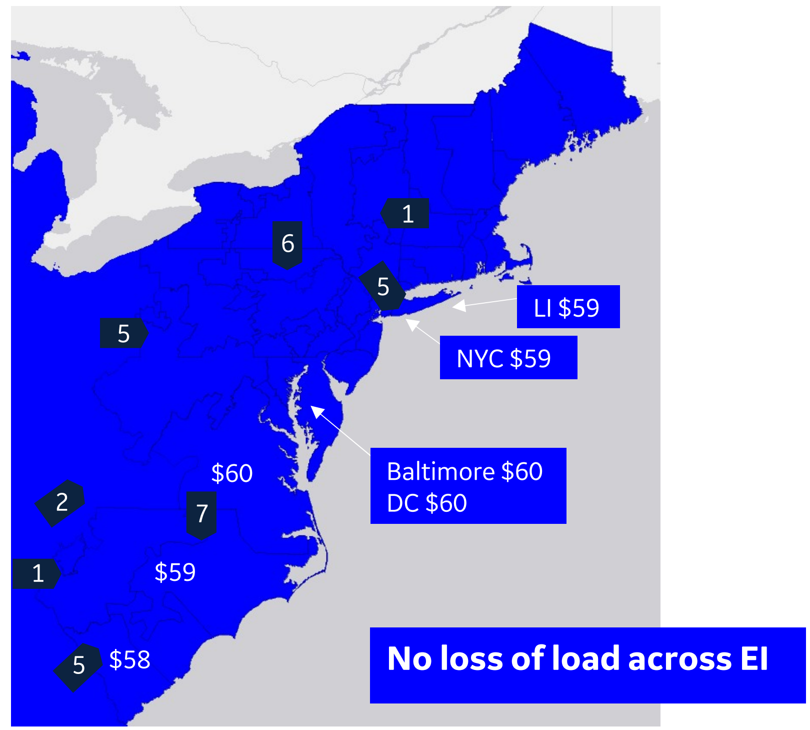
- $250+
- $200-250
- $150-200
- $100-150
- <$100

Avg. interregional flow (GW)

1

2035 UNCONSTRAINED TRANSMISSION

Higher avg. interregional power flows enabled load to be served



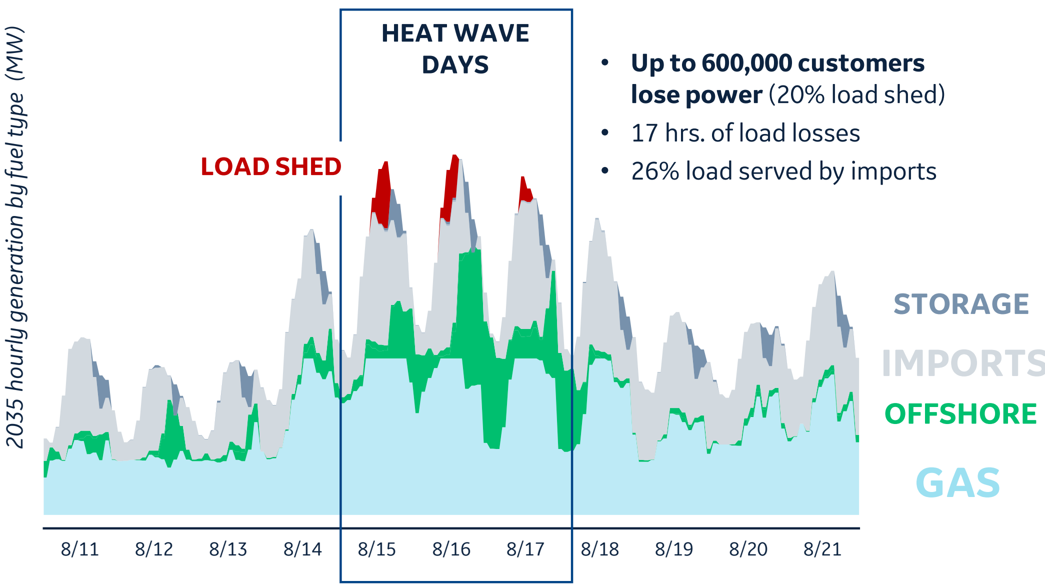
Ref: ABB Hitachi

Heat wave 2035: Up to 600,000 (20%) NYC customers lose power

Increased imports avoided power losses

2035 CONSTRAINED TRANSMISSION

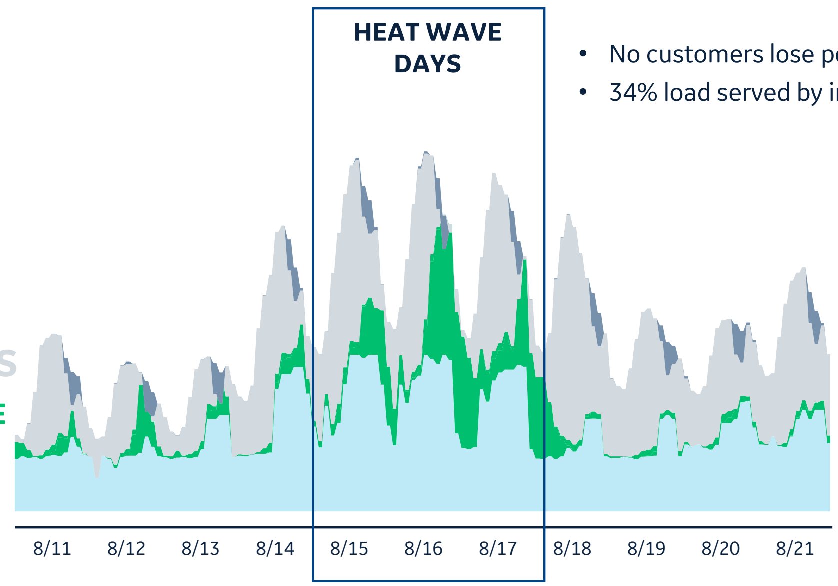
Constrained power flows led to load losses



- **Up to 600,000 customers lose power** (20% load shed)
- 17 hrs. of load losses
- 26% load served by imports

2035 UNCONSTRAINED TRANSMISSION

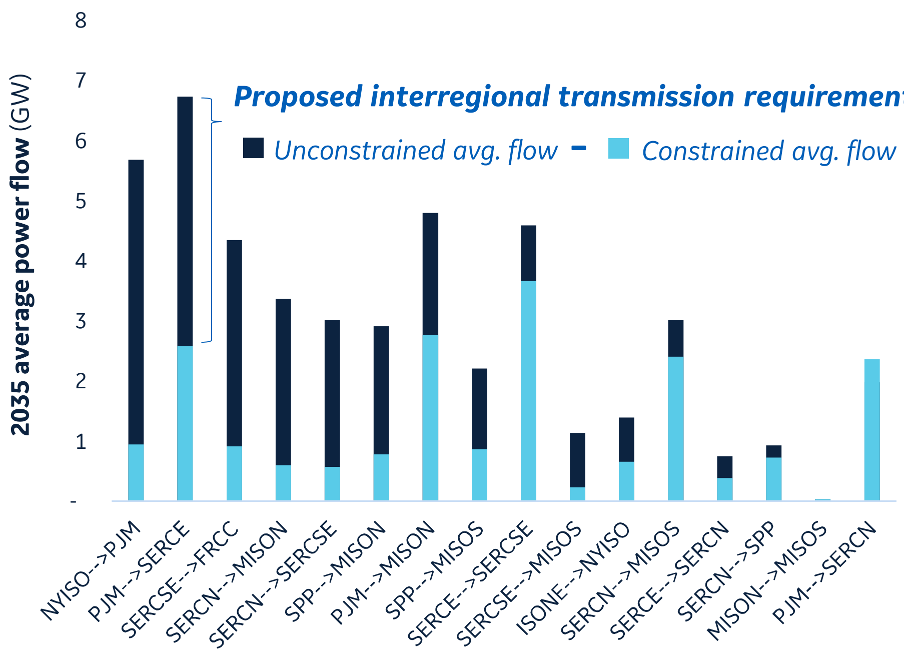
Higher imports allow load to be served



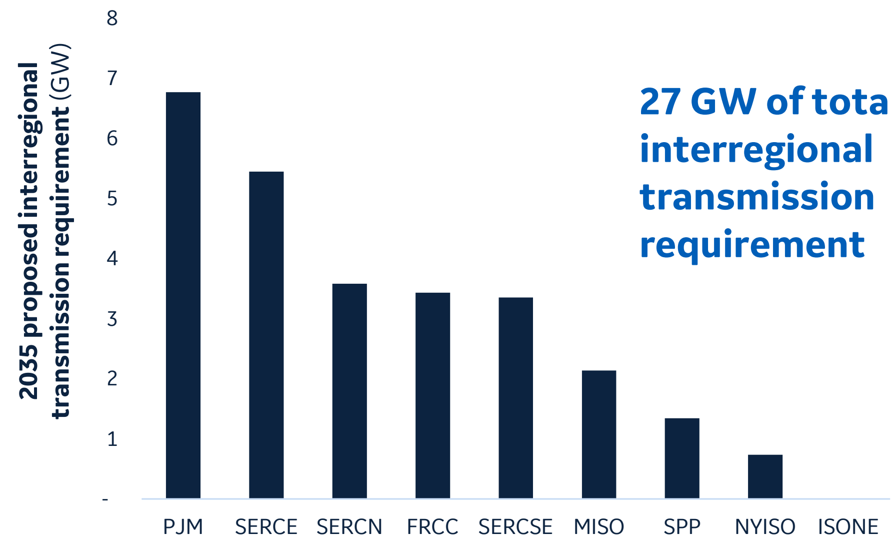
- No customers lose power
- 34% load served by imports

Average power flows can inform a *heat wave* interregional transmission requirement

Average power flow differences can be used to inform an interregional transmission requirement



Importing region can be assigned the requirement



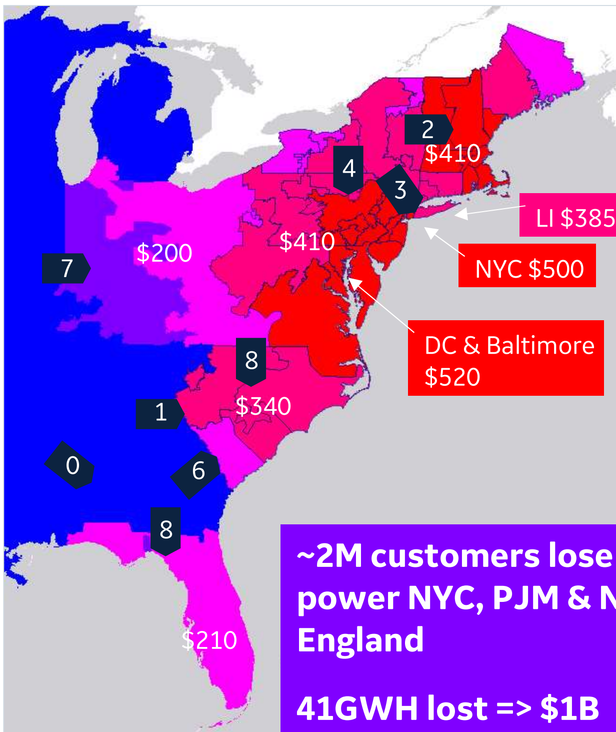
	PJM	SERCE	SERCN	FRCC	SERCSE	MISO	SPP	NYISO	ISONE
Requirement as % of peak	4%	11%	4%	3%	3%	2%	1%	1%	0%

Polar vortex 2035: Unconstraining transmission eliminates load losses

Demand increases 40%, 15% generation outages & gas price spikes to $40/MMBTU due to cold

2035 CONSTRAINED TRANSMISSION

Constrained interregional power flows led to local outages



~2M customers lose power NYC, PJM & New England

41GWH lost => $1B
(@$25k/MWH)

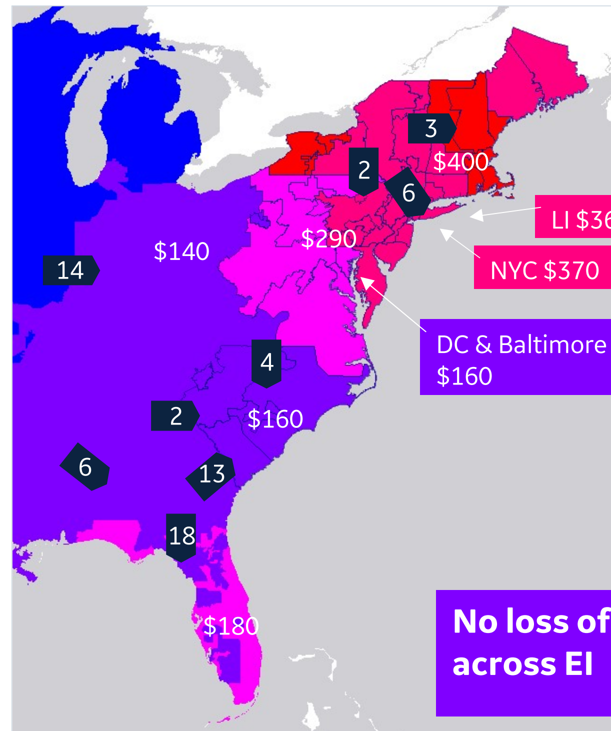
$/MWH

$400
$300
$200
$100

Avg interregional flow (GW)

2035 UNCONSTRAINED TRANSMISSION

Higher avg interregional power flows alleviated supply constraints



No loss of load across EI

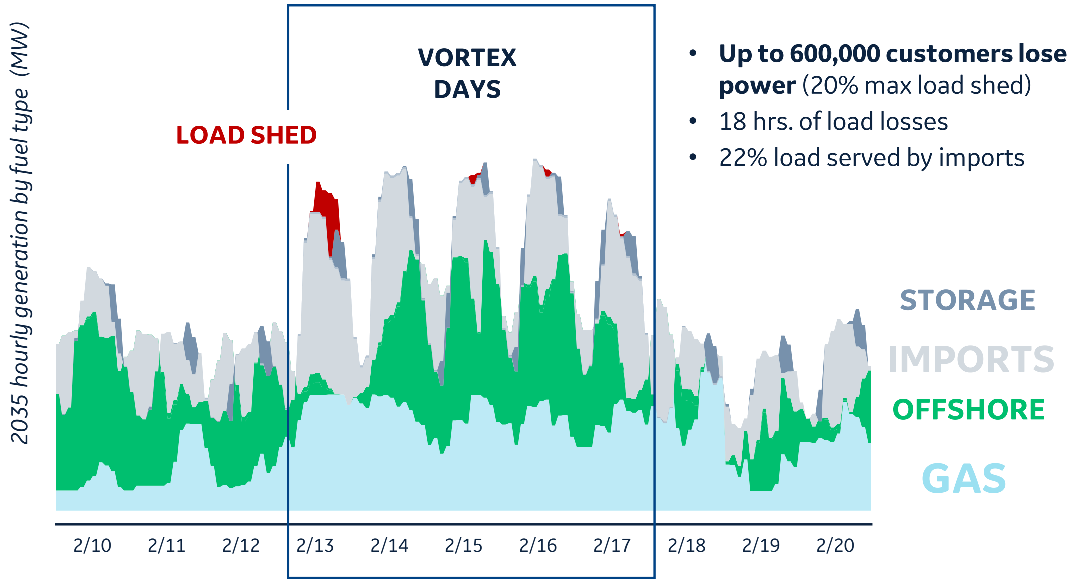
Ref: ABB Hitachi

*Constraints w/ Canada not relaxed

Polar vortex 2035: Up to 600,000 (20%) NYC customers lose power

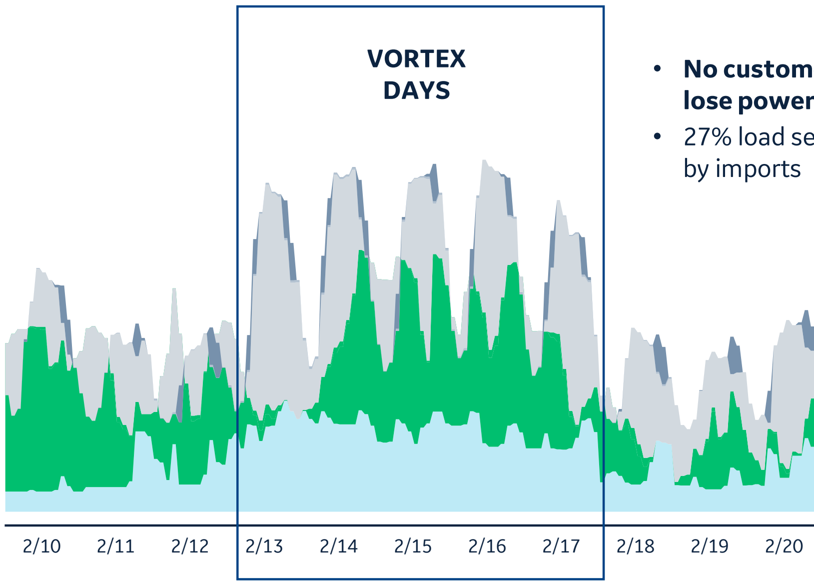
Increased imports avoided power losses

2035 CONSTRAINED TRANSMISSION
Constrained power flows led to load losses



- **Up to 600,000 customers lose power** (20% max load shed)
- 18 hrs. of load losses
- 22% load served by imports

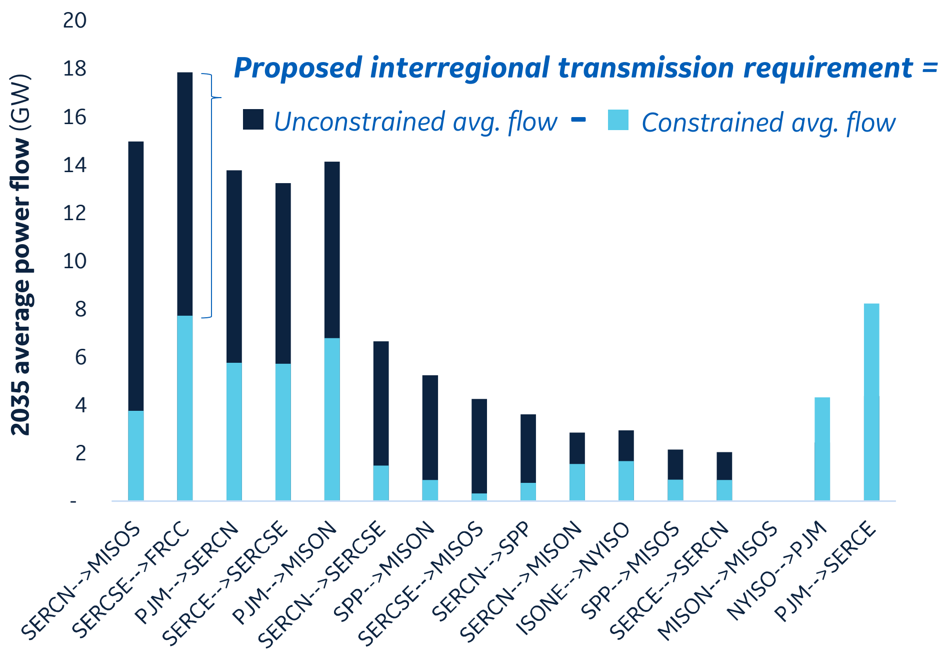
2035 UNCONSTRAINED TRANSMISSION
Higher imports allow load to be served



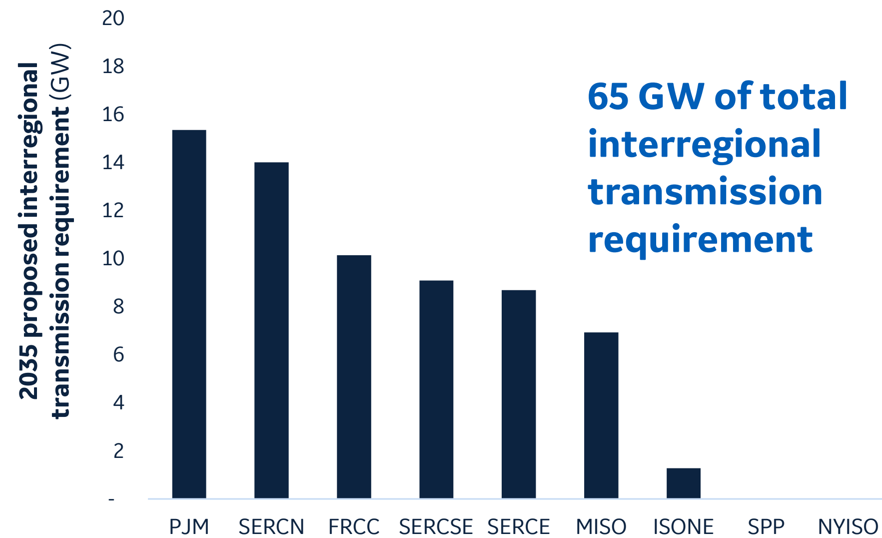
- **No customers lose power**
- 27% load served by imports

Average power flows can inform a *polar vortex* interregional transmission requirement

Average power flow differences can be used to inform an interregional transmission requirement



Importing region can be assigned the requirement



	PJM	SERCN	FRCC	SERCSE	SERCE	MISO	ISONE	SPP	NYISO
Requirement as % of peak	9%	32%	17%	20%	17%	5%	5%	0%	0%

Summarizing the interregional transmission requirement: Consider average power flows across the weather scenarios

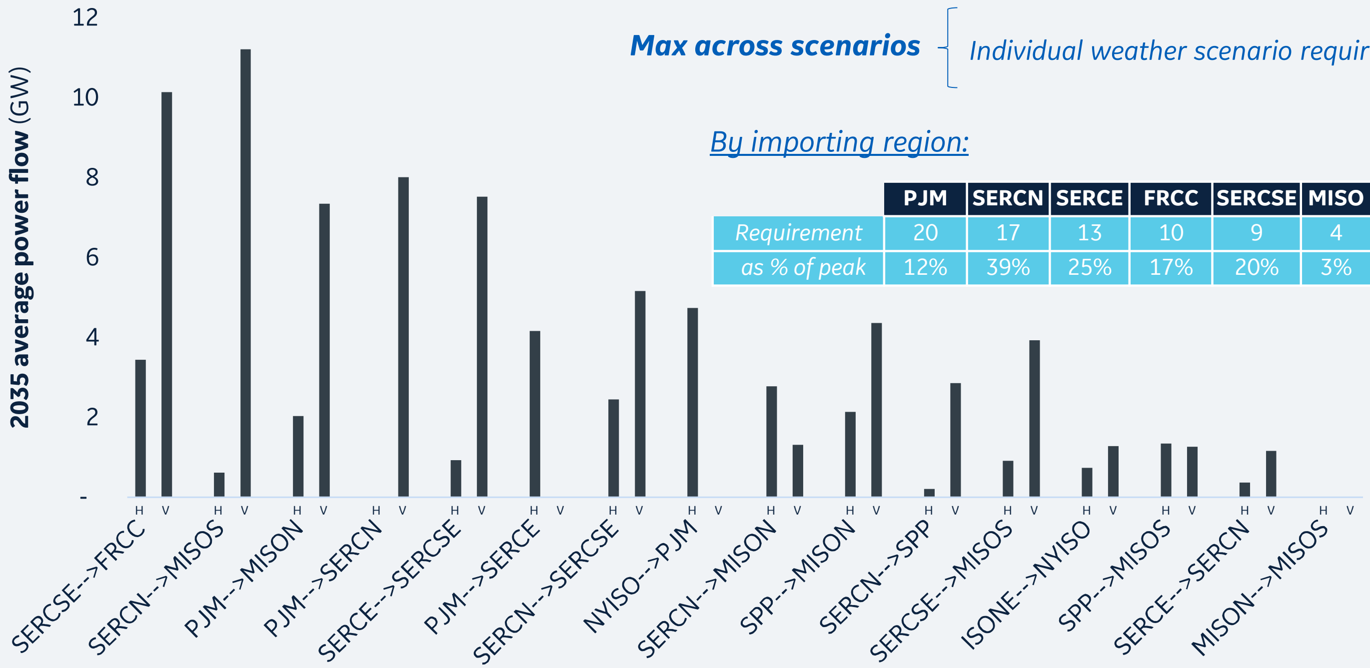
Proposed interregional transmission requirement =

Max across scenarios { *Individual weather scenario requirement* }

By importing region:

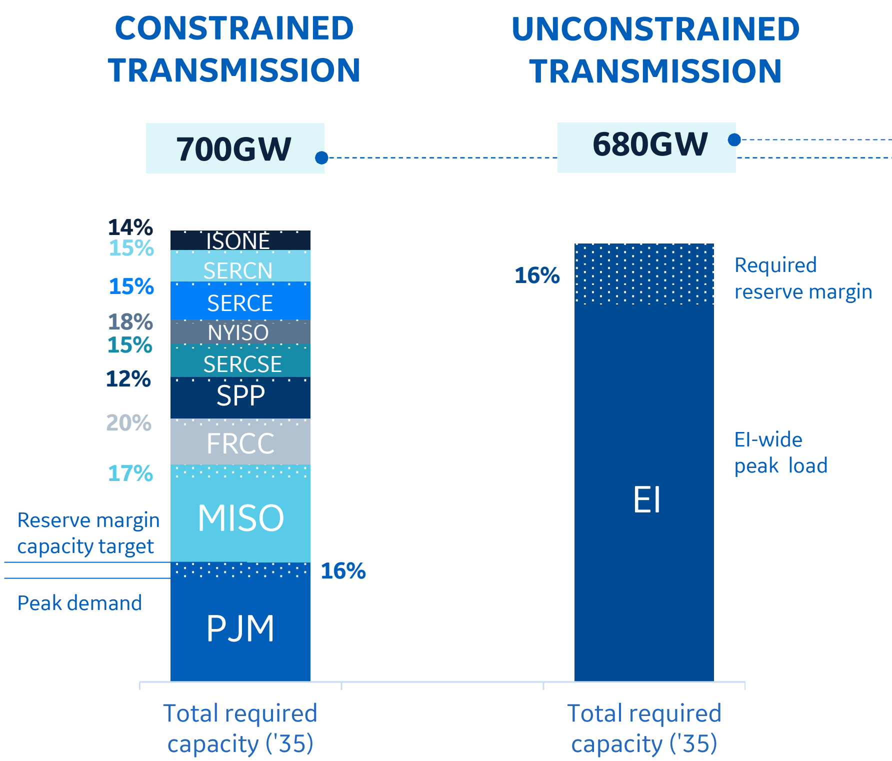
	PJM	SERCN	SERCE	FRCC	SERCSE	MISO	ISONE	SPP	NYISO
Requirement	20	17	13	10	9	4	1	1	0
as % of peak	12%	39%	25%	17%	20%	3%	5%	2%	0%

76 GW total interregional transmission requirement



Avg. power flows across 2 weather cases
H=Heat Wave
V=Polar Vortex

Unconstraining transmission lowers total capacity requirement saving ~$2B in 2035



UNCONSTRAINING TRANSMISSION LOWERS CAPACITY NEED

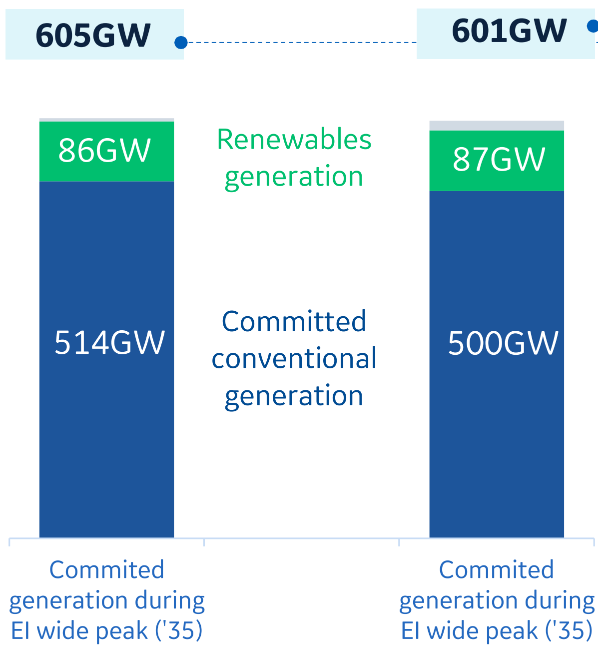
Δ = **20GW** lower capacity requirement

= **$2B** value @$104/kW '35 CONE

Total required capacity lower due to interregional diversification

Unconstraining transmission lowers spinning reserve needs saving ~$50M/year in 2035

CONSTRAINED TRANSMISSION | **UNCONSTRAINED TRANSMISSION**



UNCONSTRAINING TRANSMISSION UNLOCKS EXCESS SPINNING RESERVES

Δ **= 4GW** lower spinning reserve requirement

~$50M/yr value @$1.51/MWH PJM average price

Total required spinning reserves lower due to sharing of reserves across larger footprint

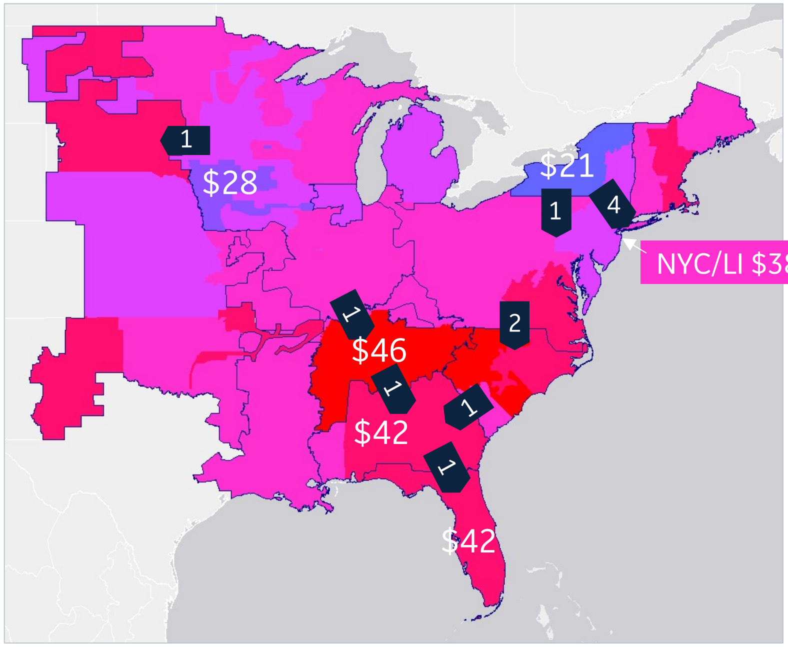
Additional economic benefits likely given sharing of other reliability services

$3B in production cost savings w/expanded interregional power flows

Could unconstrained power flows inform a minimum interregional transmission requirement?

2035 Constrained transmission
Average interregional power flows

2035 Unconstrained transmission
Higher average interregional power flows

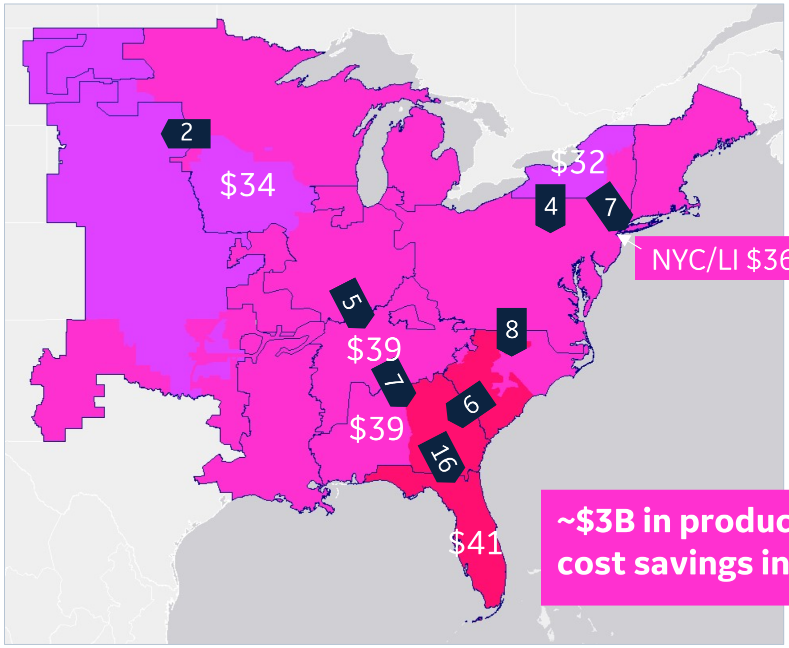


Avg LMP $/MWH

$45
$40
$35
$30
$25

Avg interregional flow (GW)

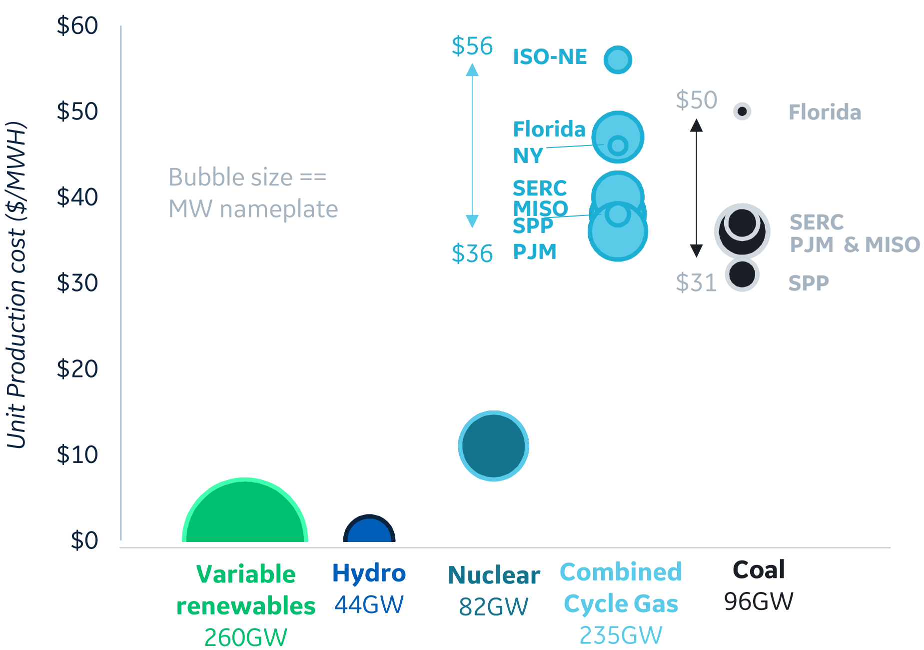
1



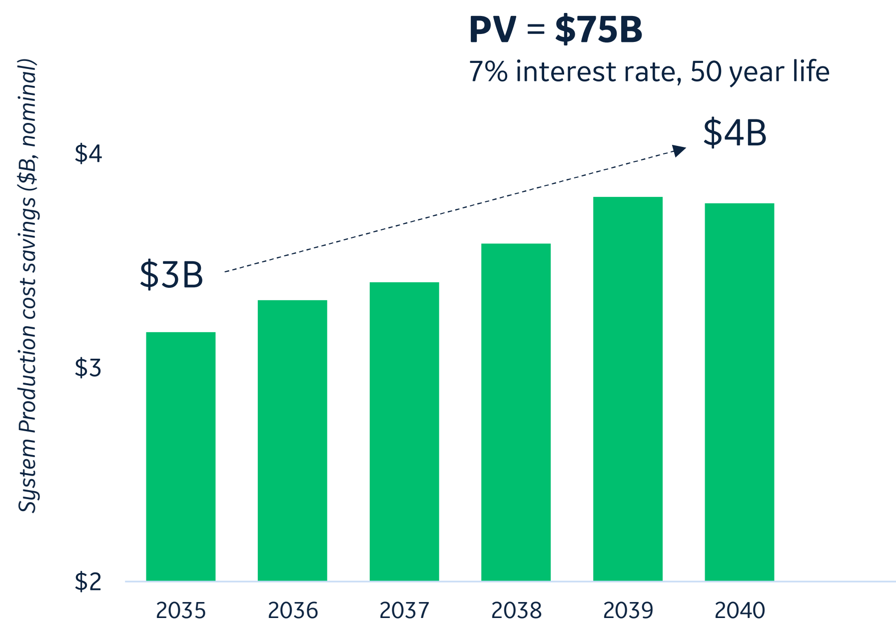
Ref: ABB Hitachi

Interregional transmission enables ratepayer savings via access to lower cost generation

Transmission allows high-cost regions like Florida and New England to access lower cost generation



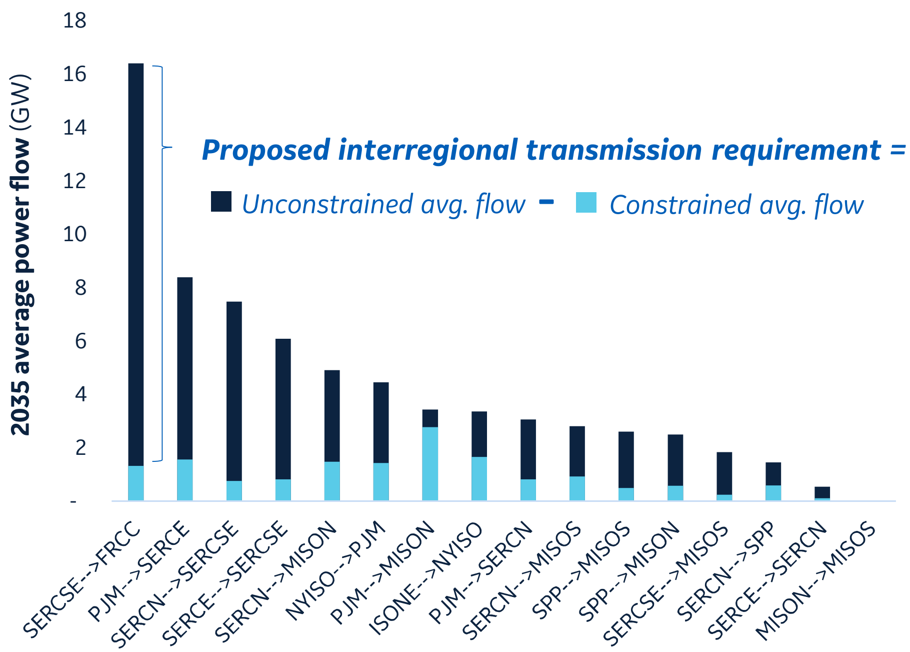
Using lower cost generation saves ratepayers $4B/year by 2040



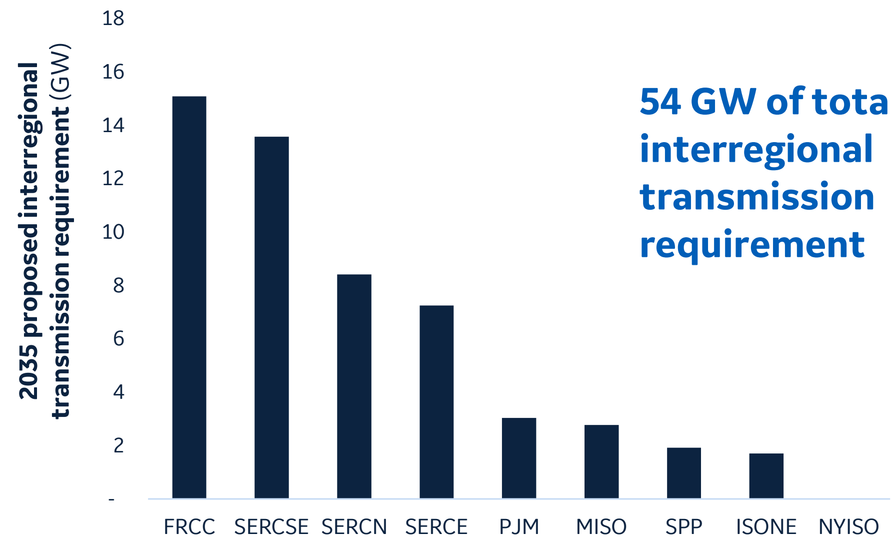
Ref: GE Energy Consulting non-proprietary database

Average power flows can inform an *affordability* interregional transmission requirement

Average power flow differences can be used to inform an interregional transmission requirement



$48B estimated transmission cost … importing region can absorb costs

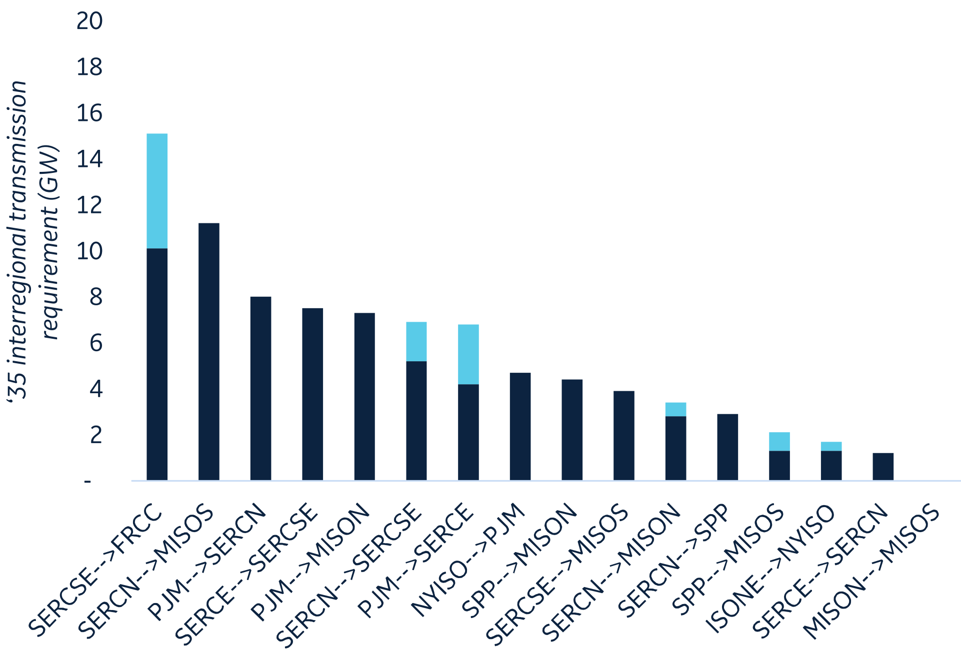


	FRCC	SERCSE	SERCN	SERCE	PJM	MISO	SPP	ISONE	NYISO
Requirement as % of peak	25%	30%	19%	14%	2%	2%	3%	6%	0%

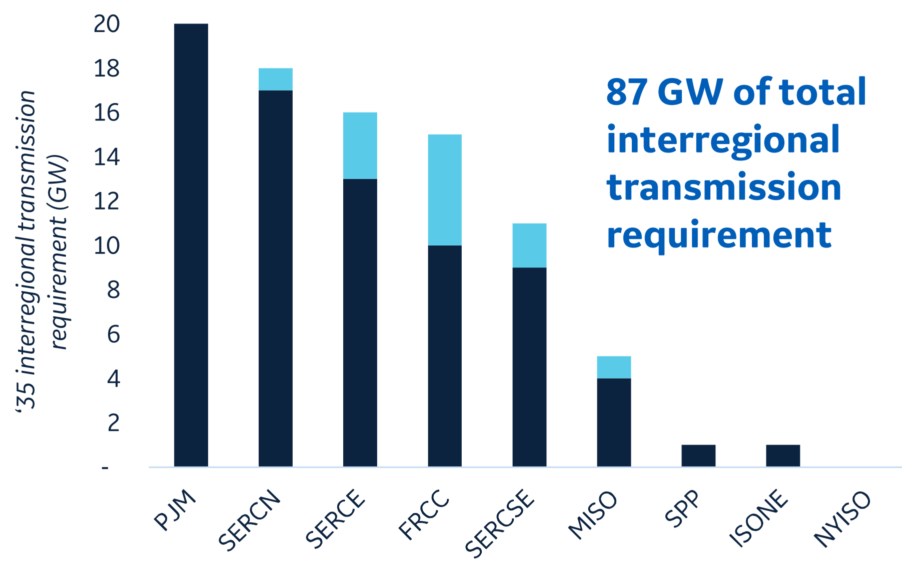
Total interregional transmission requirement will have two components

Total interregional transmission requirement = *Resiliency component* + *Affordability component*

Affordability and resilience components by interregional interface



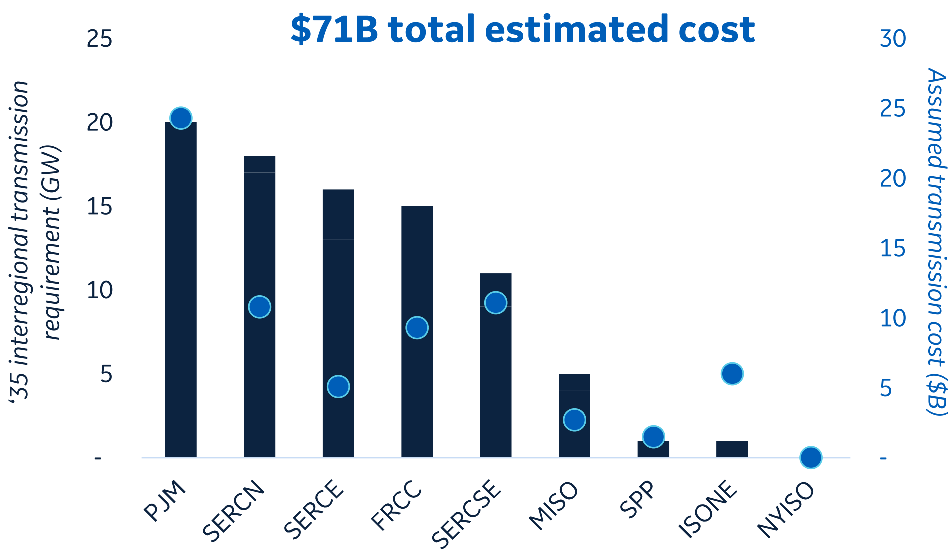
Components by importing region



Requirement as %peak	12%	40%	30%	25%	24%	4%	2%	6%	0%

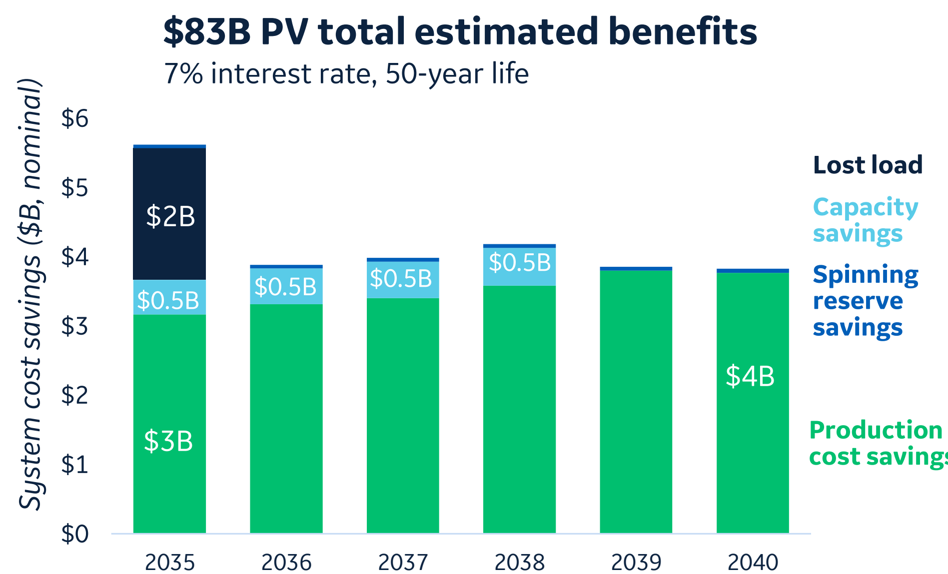
Total interregional transmission pays for itself in total benefits

$71B estimated transmission cost … importing region can absorb costs



Cost assumptions
500MW/tie line
100 mi @$3M/mi in 2035
NYISO interfaces: 50 mi @$30M/mi

$83B estimated total benefits … likely higher given additional ancillary savings



Benefit assumptions
Capacity build over 4 years
$25,000/MWH loss of load cost
Extreme events every 10 years

Should interregional transmission requirements consider stability?

Interregional transmission requirements may need to go beyond AC lines to strengthen grid

As resources diversify, grid stability is increasingly a factor in resilience

The interregional grid can have adequate generation & transmission but still be unstable

- ❑ Stable **frequency** & **voltage** (e.g. 60Hz & 230kV)
- ❑ Stable during **normal** conditions
- ❑ Stable after a **disturbance** (i.e. generator trips, tree hits a line … often in storms, wildfires + cascading)

An interregional AC transmission requirement may be insufficient for a stable grid

Potential screening methodology

Step 1: **Is grid stable** w/ incremental interregional AC transmission requirement?

PASS /FAIL

- ☐ **Weak grid?** Short circuit current ratio acceptable (e.g. SCR>3)?
- ☐ **Stable frequency?** Synchronous unit headroom acceptable?
- ☐ **Small signal instabilities**? Unwanted resonances?

If all pass: **Great! The AC requirement is sufficient**

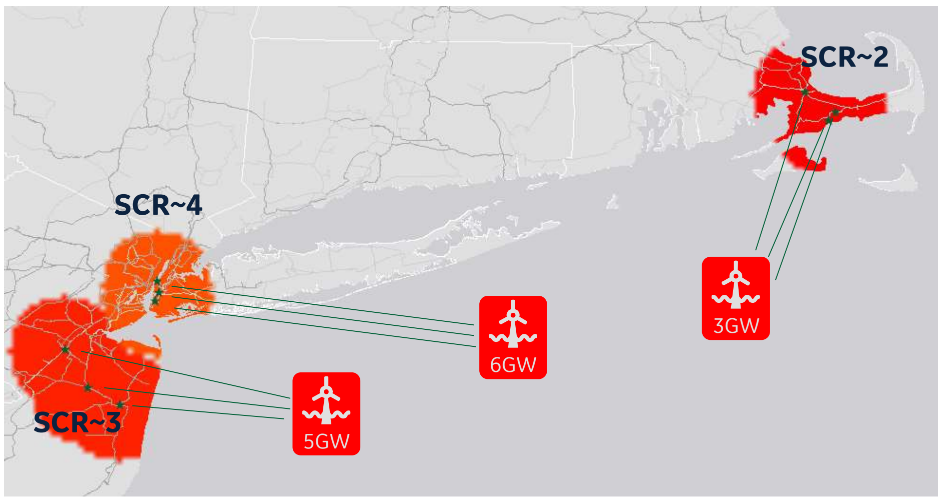
If any fail: **Requirement to include a qualifier to reinforce until all pass**

Interregional transmission may need to consider beyond AC lines for extreme weather stability

Example: Even with significant AC interregional reinforcement, Eastern seaboard grid remains weak

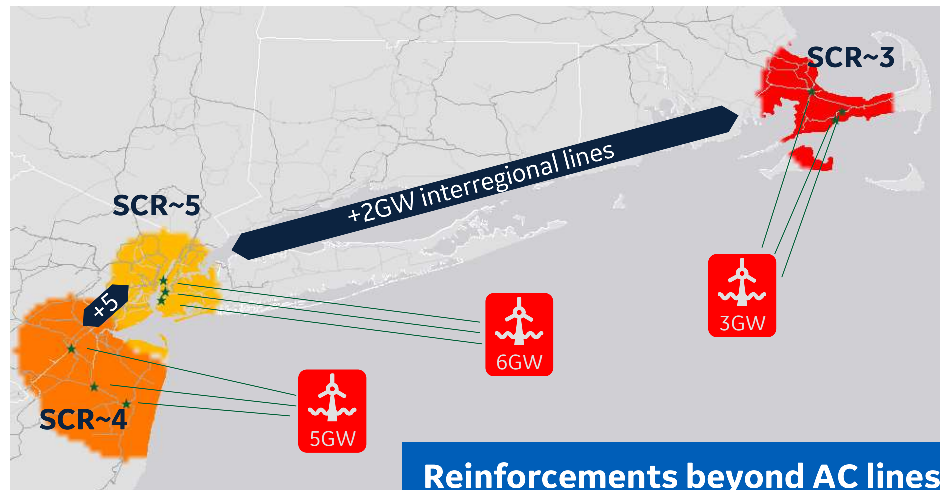
2035 CONSTRAINED TRANSMISSION

Weak grid onshore and offshore



2035 EXPANDED INTERREGIONAL TRANSMISSION

Onshore grid strengthened … offshore grid still weak



★ Assumed offshore POIs

Assumed incremental interregional transmission (GW)

<3 SCR >10

WEAK STRONG

Reinforcements beyond AC lines may be needed to strengthen grid

- DC vs. AC connections
- Synchronous condensers
- Grid forming controls

Ref: ABB Hitachi

Ongoing GE work

Including resiliency economic benefit via constrained vs. unconstrained reserve margins

CONCLUSIONS THUS FAR

~$3-4B/year production cost savings enabled by unconstraining interregional transmission under normal weather conditions

Load shedding avoided during simulated heat wave and polar vortex events via unconstrained transmission

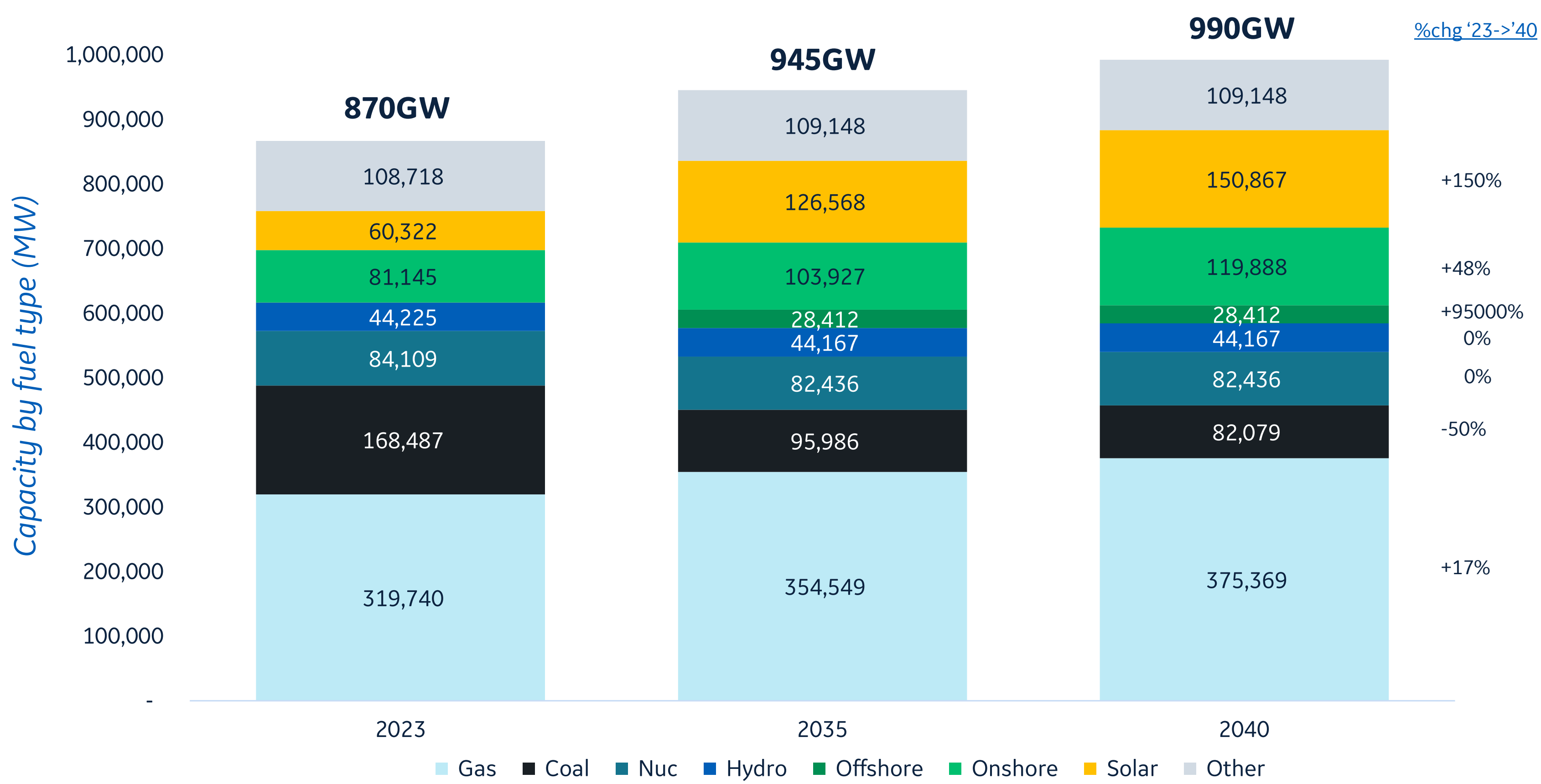
GE proposed a methodology for quantifying incremental interregional transmission requirement via increase in average power flows enabled by unconstraining transmission across weather events

FERC can consider this methodology to enable the definition of an incremental transmission requirement between each pool in its jurisdiction. Cost allocation could follow importing region.

Building a world that works

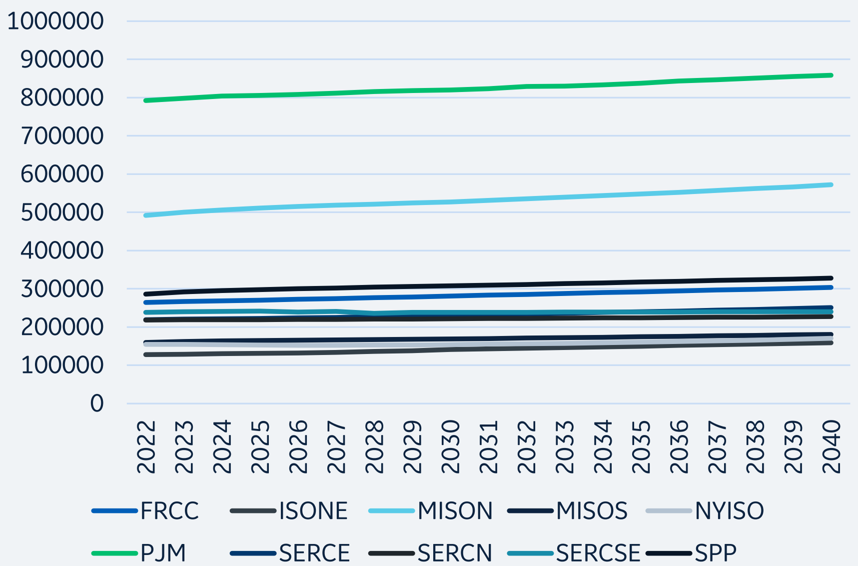
Assumptions

Renewables and gas grow … coal declines

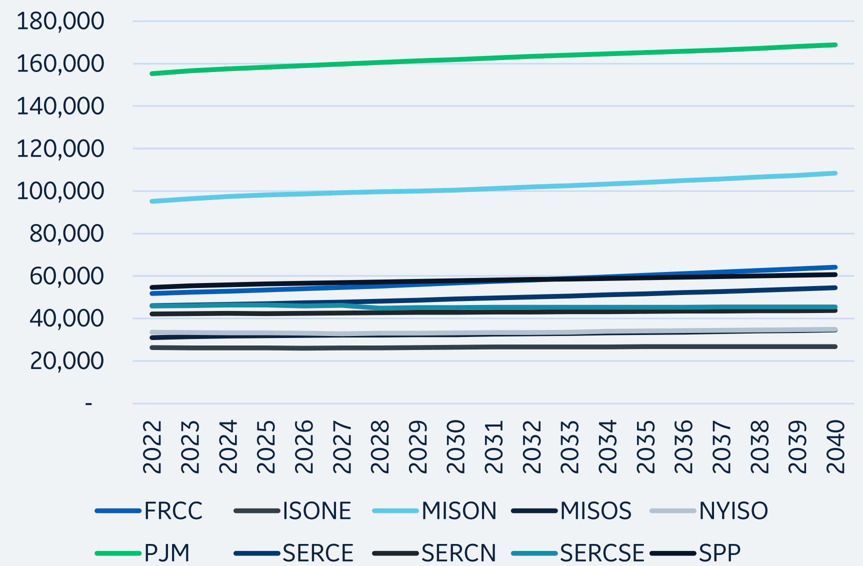


Load growth ~1%/year across pools … steeper growth 2040+

Energy demand by pool and year (GWH)



Peak load by pool and year (MW)



GE Energy Consulting load assumptions come directly from RTO-issued forecasts.
Most recent forecasts included higher load assumptions given expected electrification

Henry Hub gas price assumption: long term prices rising

GE then calculates delivery charges to electric generators across the US