Synapse
Energy Economics, Inc.

Electric Grid Structures

NESEA BuildingEnergy 14

Understanding Our Energy Distribution Systems

March 5, 2014

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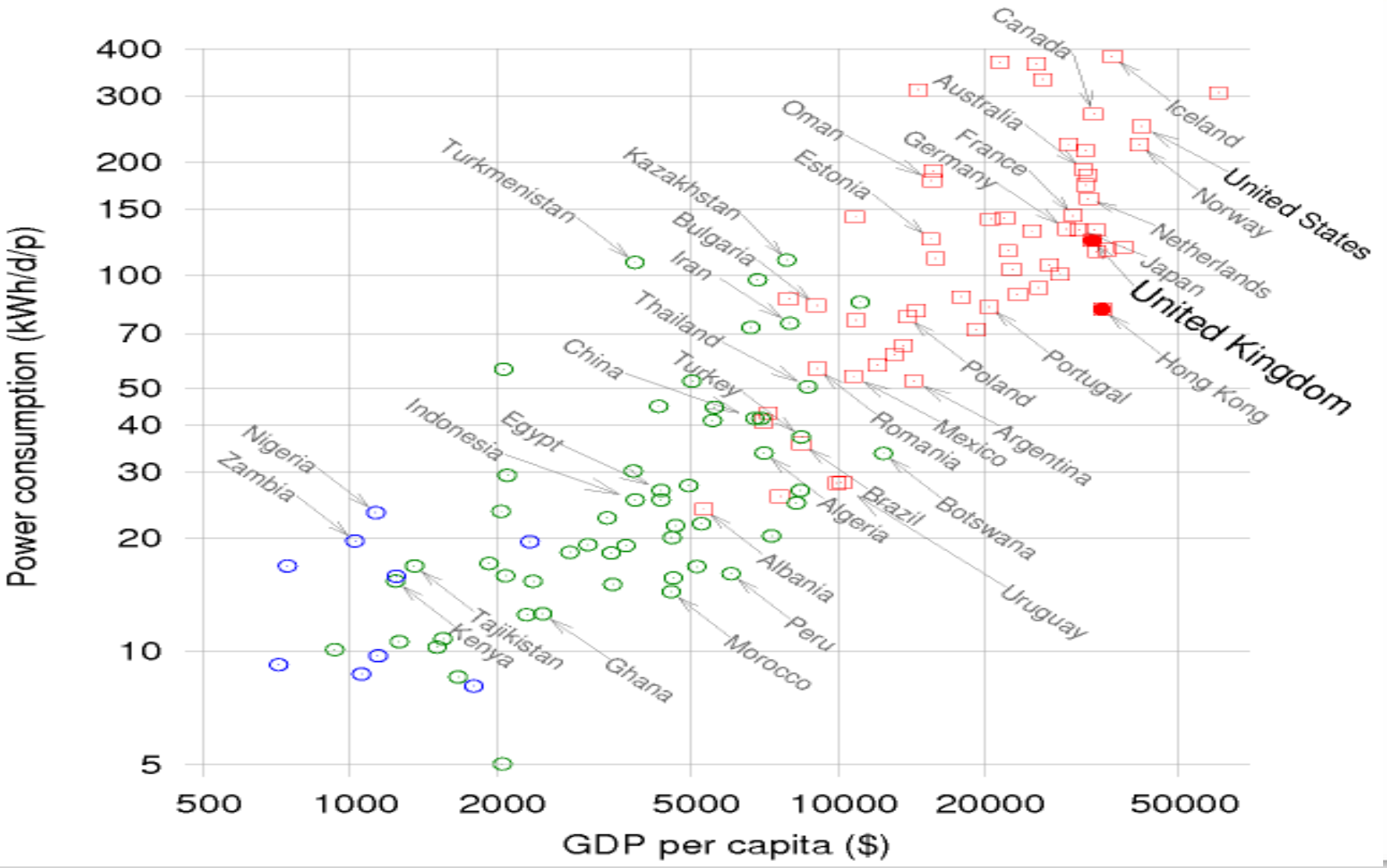
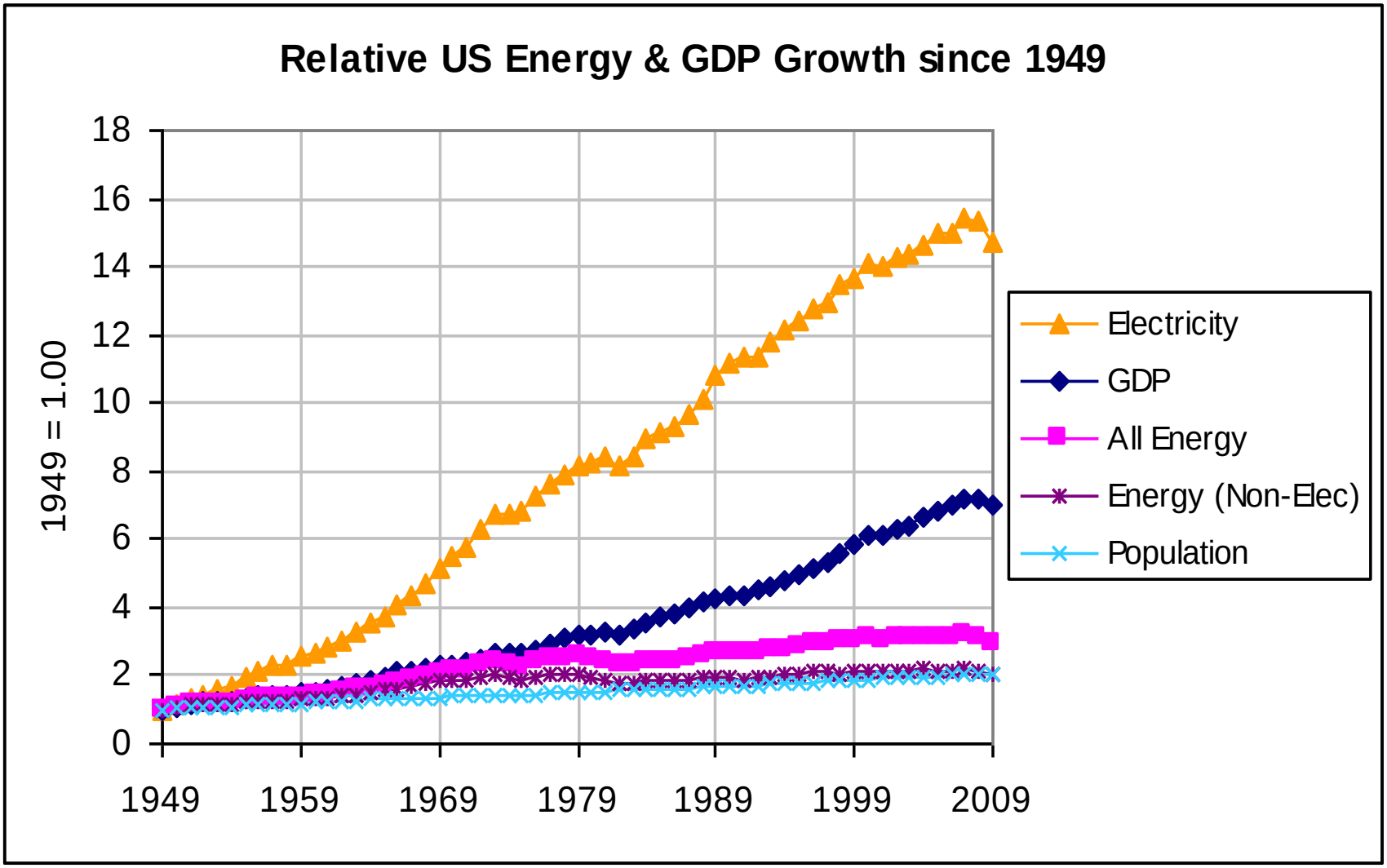
Synapse Energy Economics

- Consulting firm in Cambridge Massachusetts with a staff of 30 people
- Issues
  - Electric industry restructuring & utility rate cases
  - Wholesale markets, ISOs, and RTOs
  - System Planning and resource development
  - Environmental impacts of power industry
- Clients
  - State Consumer Advocates and Utility Commissions
  - Public Interest and Environmental groups
  - EPA and DOE
  - RTO stakeholders

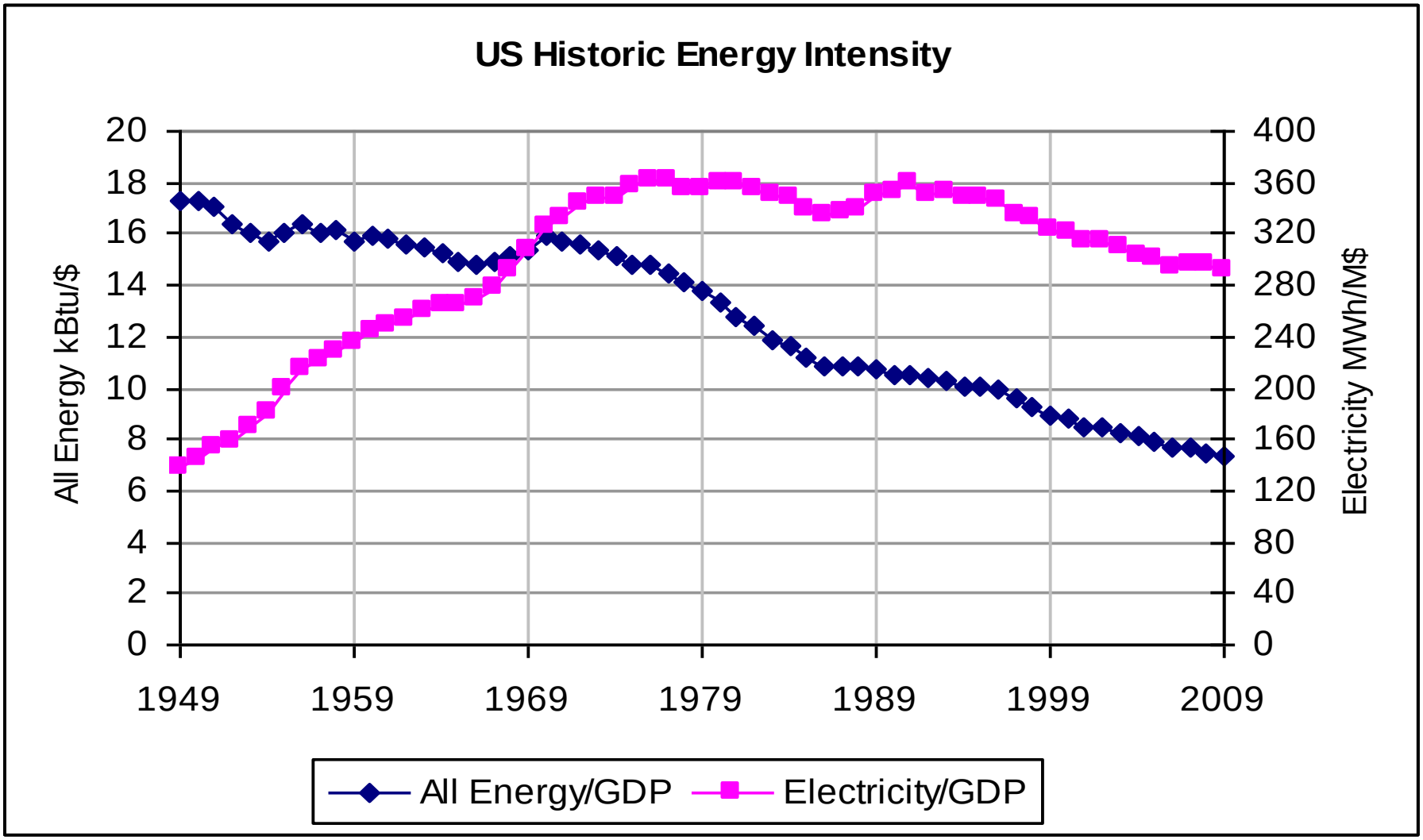
Energy Intensity



Trends


Relative US Energy & GDP Growth since 1949
1949 = 1.00
18
16
14
12
10
8
6
4
2
0
1949
1959
1969
1979
1989
1999
2009
Electricity
GDP
All Energy
Energy (Non-Elec)
Population

Declining energy intensity



Electric machines

Three elements to power system

- Supply (resources)
- Demand (loads)
- Wires (T&D systems)

Inter-connected electric systems are the largest machines ever engineered

- 24/7 balancing of supply and demand
- Cascading effect of disruptions
- Controls for local systems

North American electric machines

New England's Electric Power Grid at a Glance

- 6-state region: 14 million residents and 6.5 million meters
- 37,000 MW of capacity resources
  - Includes generation, demand resources and imports
- 8,400 miles of high-voltage transmission
  - $5 billion in investment since 2002
  - $6 billion planned over next 5 years
- 28,130 MW all-time peak demand
- $5 billion total energy market (2012)

Planning issues

Peak Load

- Summer: MW needed for summer peak day
- Winter: MW needed for winter peak day
- Daily: MW needed for each daily peak

Energy

- MWH needed to meet total annual demand

Reliability Needs

- Resource adequacy (thermal loads on wires)
- Security dispatch (voltage, stability and daily operation)

System operations

- Energy to meet forecast load in each hour
  - Day Ahead, adjusted by a reliability review
  - Real Time
- Reserves to be available for contingencies
  - 10 minute
  - 30 minute
- Dispatch instructions to fine tune/balance
  - Voltage
  - Regulation to fine tune the balance
- Capacity to meet annual peak load

New England grid

Traditional operation of power grids

- Day-ahead forecast of hourly loads (weather)
- Day-ahead commitment of generation
- Real-time management of generation by operators

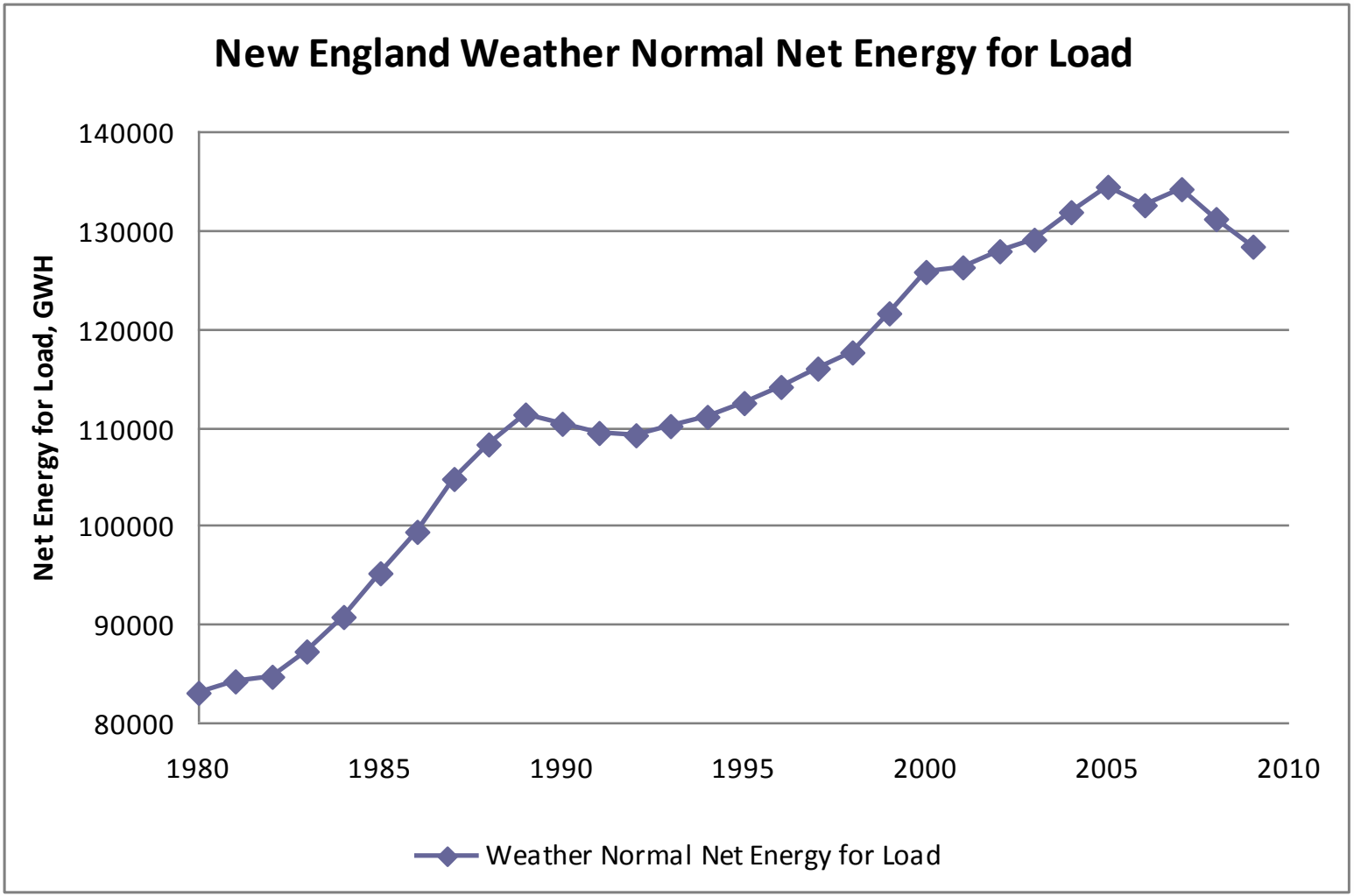
Evolving operation of power grids

- Day-ahead offers by Supply and Load
- Day-ahead dispatch schedule includes instructions to both Supply and Load
- Real-time balancing based on offers

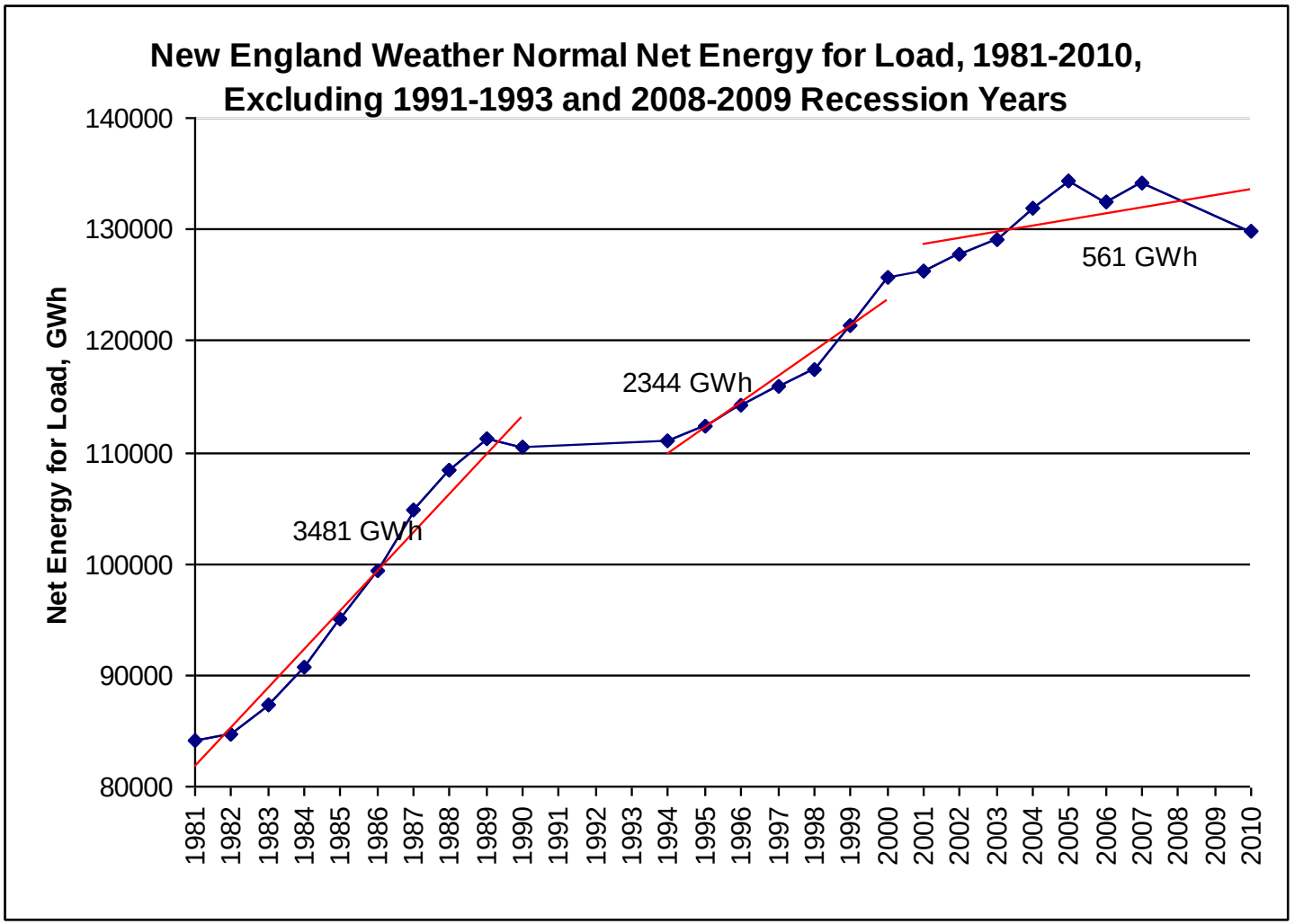
Supply and load are variable/manageable

Energy load

(1980-2009)

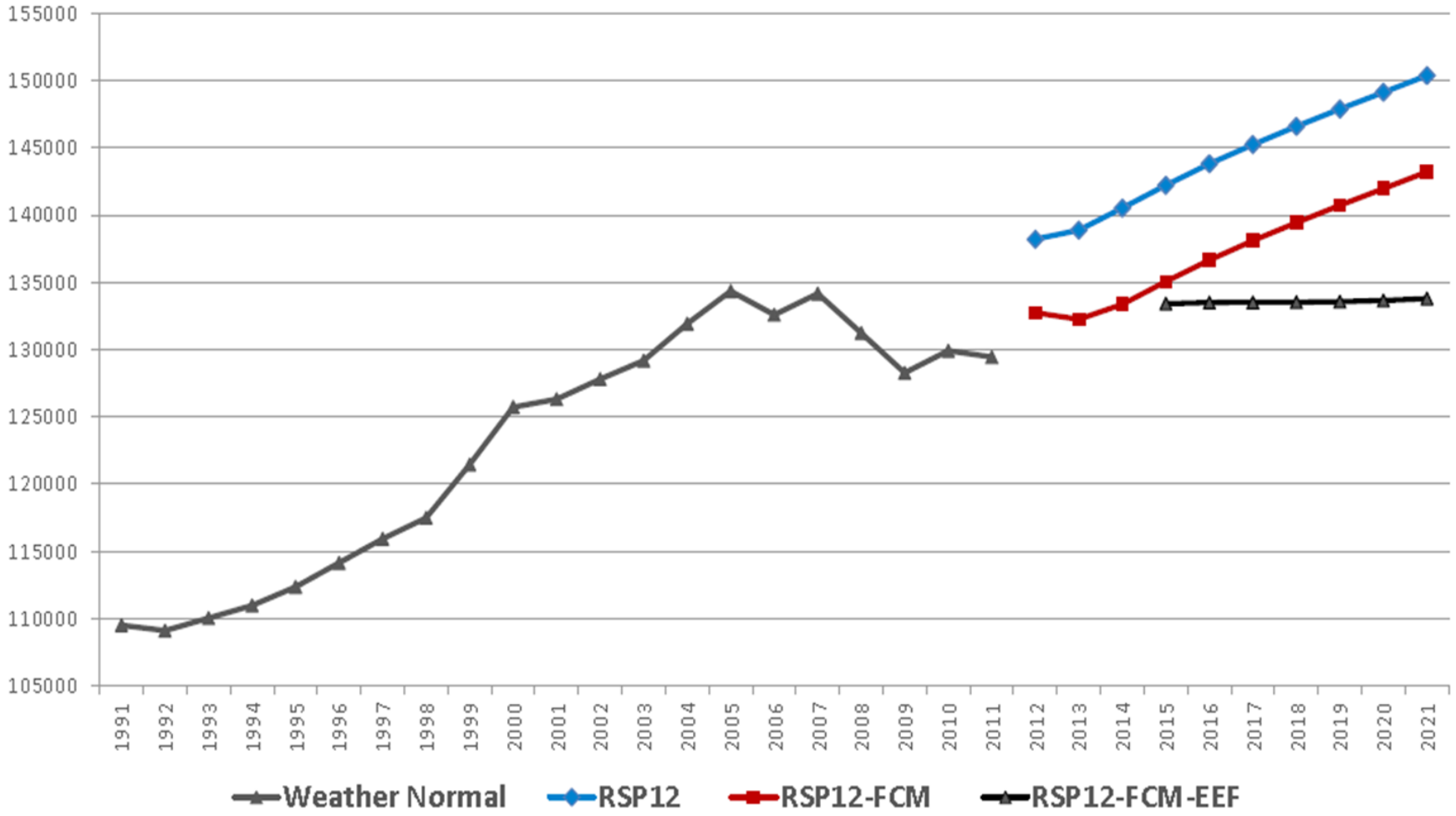


Declining slope to flat

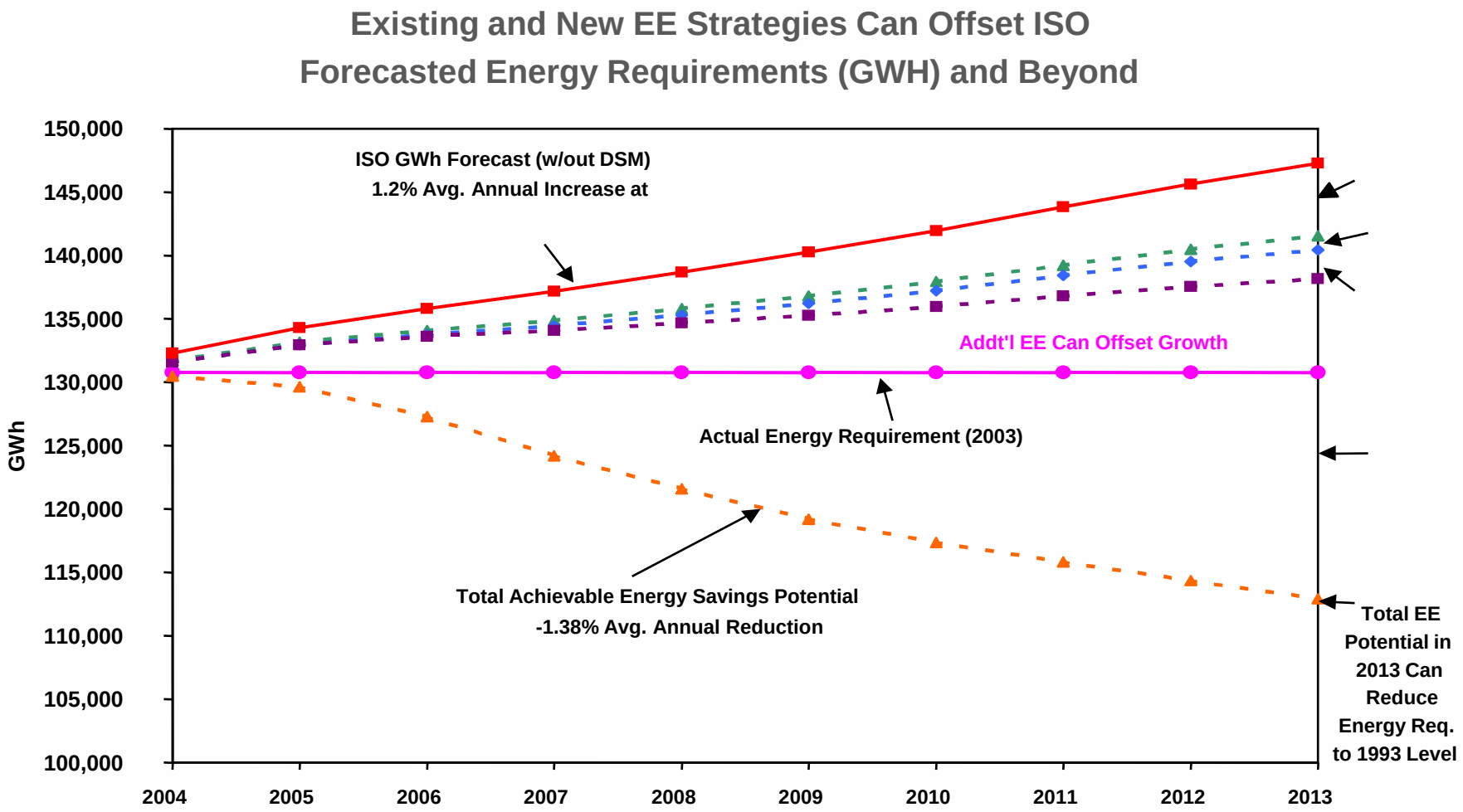


ISO-NE RSP12 annual energy (GWh)

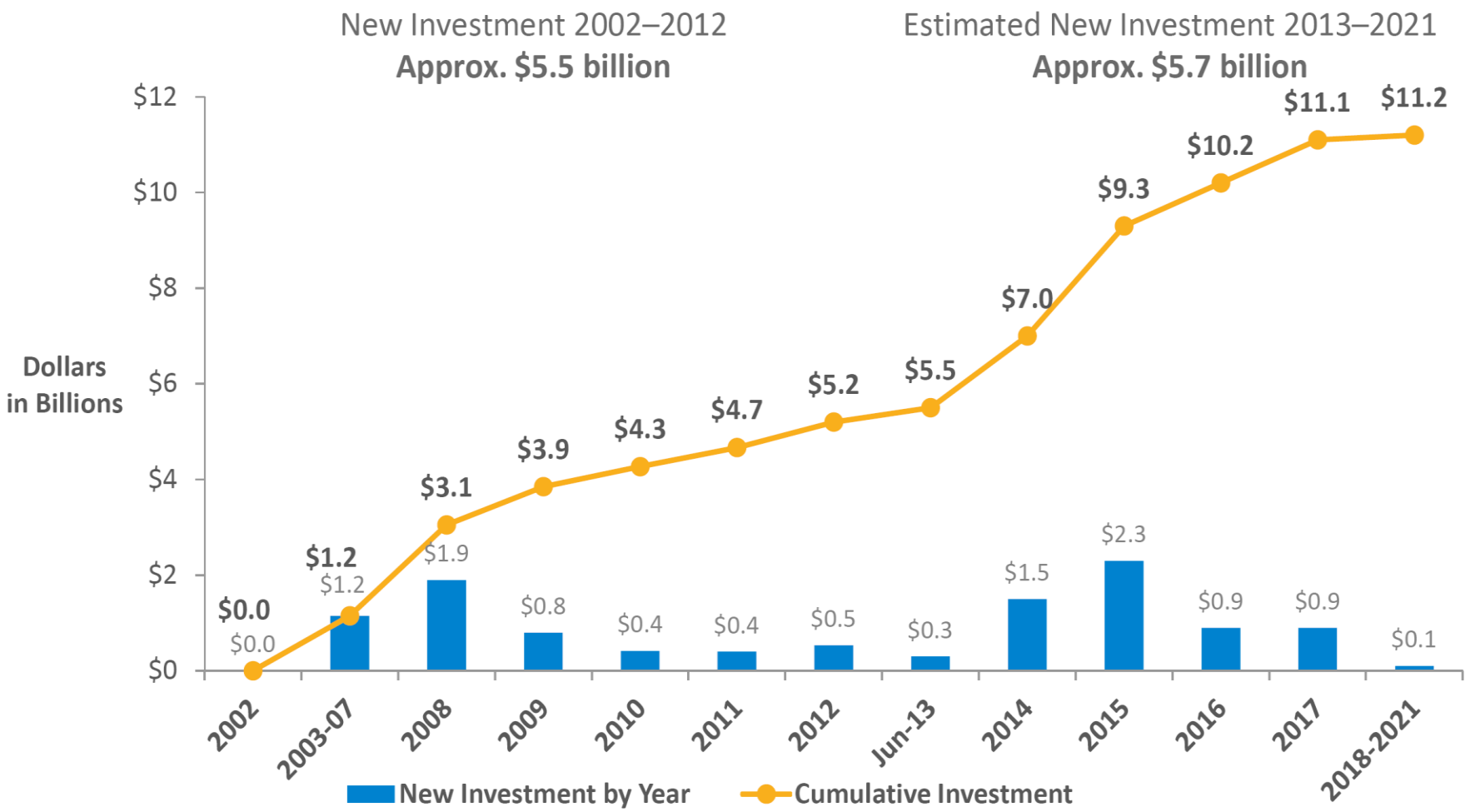
Weather Normal History 1991-2011 and Forecast 2012-2021



Northeast Energy Efficiency Partnerships 2005 estimate of EE potential

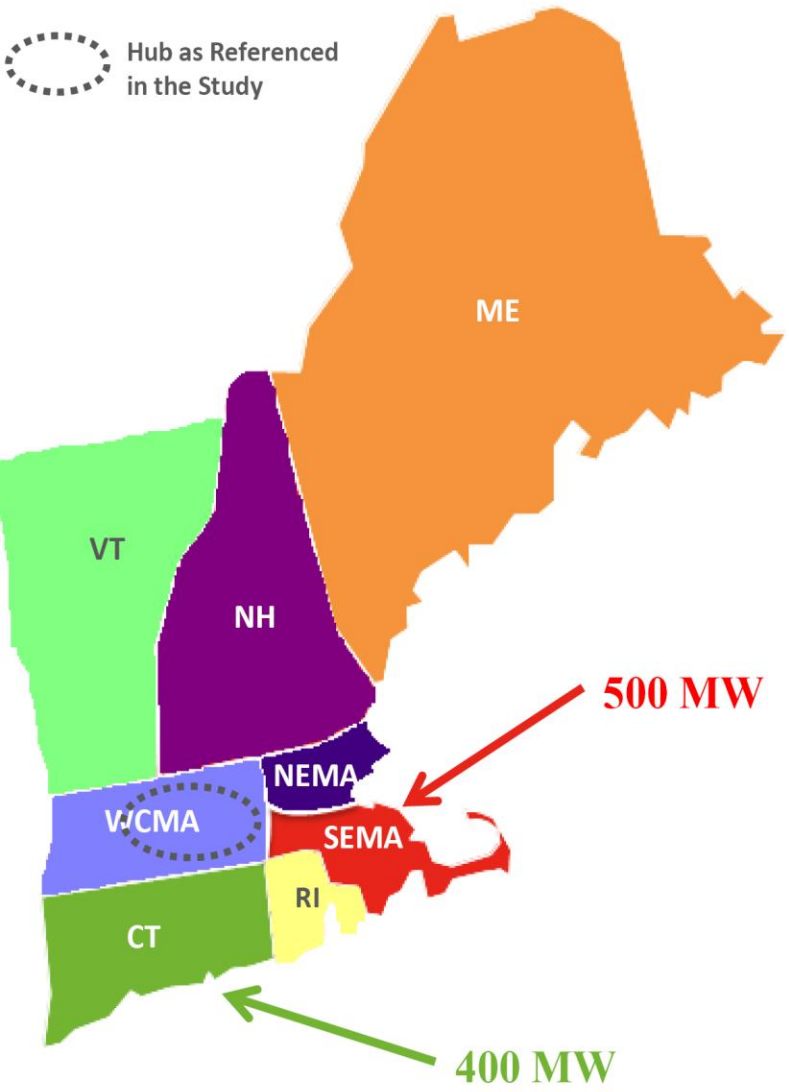


Transmission Investment in New England



Source: ISO New England Transmission Project List, through June 2013 Update.

Retirement Study Observations

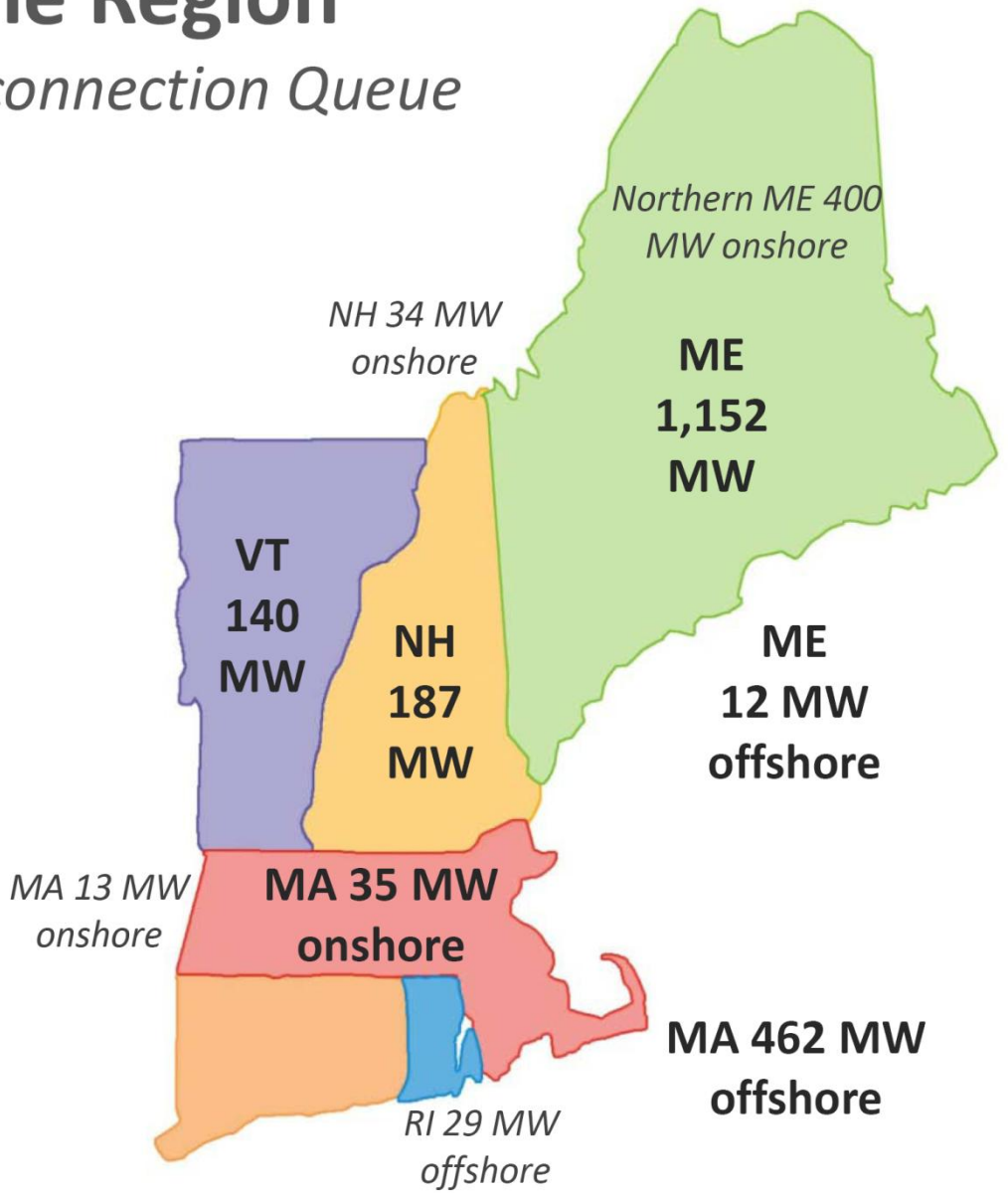


- If 8,300 MW retire by 2020, resource adequacy needs dictate replacement capacity of approximately 6,000 MW plus new energy-efficiency resources
- With currently planned system configuration, at least 900 MW of the 6,000 MW replacement capacity must be in specific locations due to transmission constraints
  - 500 MW must be in Southeastern Massachusetts
  - 400 MW must be in Connecticut
- Approximately 5,100 MW may need to be integrated into Hub
  - Transmission may be needed to make resources deliverable to the Hub
  - From the Hub, power can be delivered to much of the load

Wind Proposed for the Region

Based on April 1, 2013 Interconnection Queue

- 2,453 MW proposed (*includes non-FERC jurisdictional*)
- Majority of wind development proposals in Maine and northern New England
- Offshore projects proposed in Massachusetts, Maine, and Rhode Island



Note: FERC-jurisdictional wind project totals are bold-faced; non-FERC-jurisdictional totals are non-boldfaced; numbers may not add to 2,453 MW total due to rounding.

ISO New England DG forecast

Interim forecast for 2014 System Plan

- DG forecast working group (DGFWG)
- Focus on solar PV
- Developing state inventories

Complete forecast for 2015 System Plan

- Other DG, including CHP
- Refinement to solar PV

Operational issues are a concern

Interim PV Forecast

January 27, 2014 Draft

States	Annual Total MW (MW, AC nameplate rating)											Totals
	Thru 2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	
CT	77.1	50.6	45.6	65.6	45.6	45.6	45.6	45.6	45.6	45.6	45.6	557.9
MA	352.7	188.6	139.4	139.4	139.4	132.8	132.8	132.8	132.8	132.8	132.8	1,756.4
ME	5.0	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	20.0
NH	9.9	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	35.1
RI	10.1	8.4	6.6	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	64.7
VT	54.0	20.3	13.5	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	141.8
Annual Policy-Based MWs	508.7	271.8	209.1	220.7	195.8	189.2	146.6	146.6	13.8	11.3	1.5	1,915.1
Annual Post-Policy MWs	0.0	0.0	0.0	0.0	5.0	5.0	47.5	47.5	180.3	182.9	192.7	660.8
Annual Nondiscounted Total (MW)	508.7	271.8	209.1	220.7	200.7	194.1	194.1	194.1	194.1	194.1	194.2	2,575.9
Cumulative Nondiscounted Total (MW)	508.7	780.5	989.7	1,210.4	1,411.2	1,605.3	1,799.4	1,993.5	2,187.6	2,381.7	2,575.9	2,575.9

Discounted MWs

Total Discounted Annual	508.7	244.7	177.8	176.6	148.1	143.1	121.8	121.8	55.4	54.2	49.3	1,801.4
Total Discounted Cumulative	508.7	753.4	931.1	1,107.7	1,255.8	1,398.9	1,520.7	1,642.6	1,698.0	1,752.1	1,801.4	1,801.4

Final Summer SCC (MW) Based on 35% [Assume Winter SCC equal to zero]

Annual: Total Discounted SSCC (MW)	178.0	85.6	62.2	61.8	51.8	50.1	42.6	42.6	19.4	19.0	17.3	630.5
Cumulative: Total Discounted SSCC (MW)	178.0	263.7	325.9	387.7	439.5	489.6	532.3	574.9	594.3	613.2	630.5	630.5

Notes:

(1) Yellow highlighted cells indicate that values contain post-policy MWs

(2) Some "Thru 2013" values must be reconciled with distribution queue data

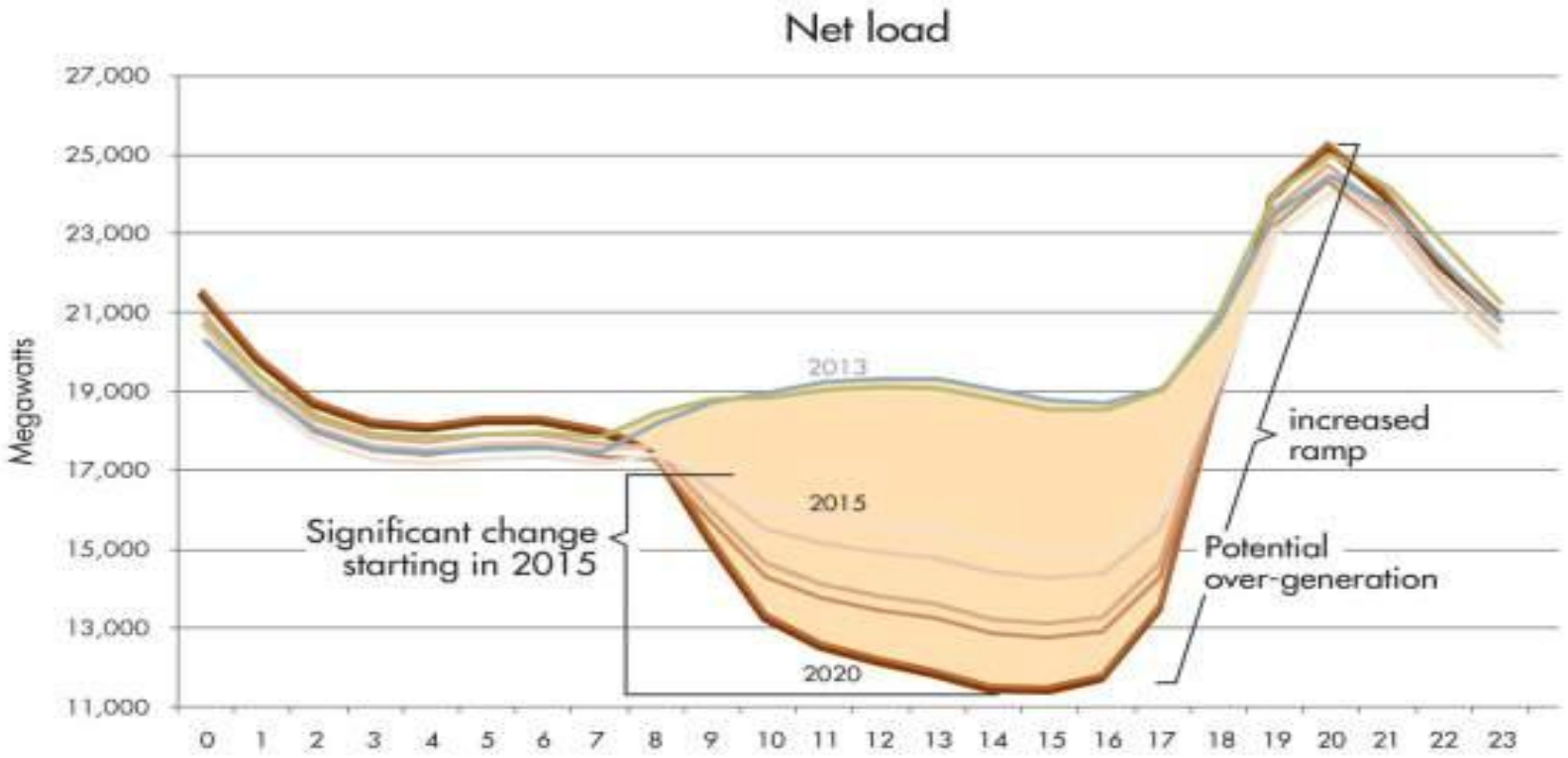
(3) All values are not final and are subject to change based on updated data and stakeholder input

2013 New England market changes

- Change timing of Day Ahead Market (gas)
- Expand use of daily reoffer period
- Winter 2013-2014 fuel purchases (gas)
- Increase quantity of operating reserves
- Increase frequency of higher reserve prices
- Update shortage event trigger (30 min)
- Refer non-performing generators to FERC
- FCA-8 retirements and scarcity
- FCA-9 design changes (proposed)

CAISO Duck Curve

Growing need for flexibility starting 2015



California ISO

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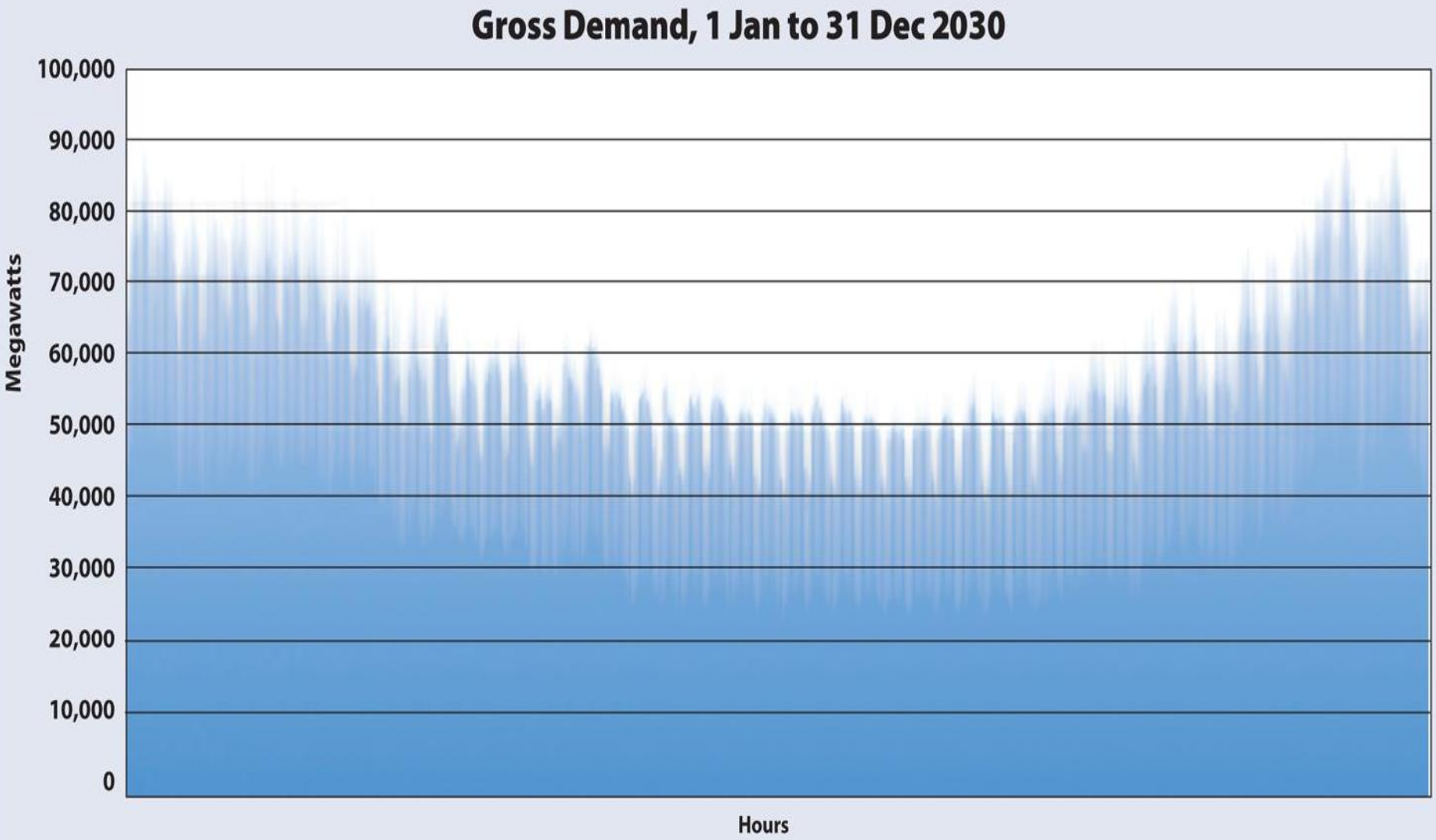
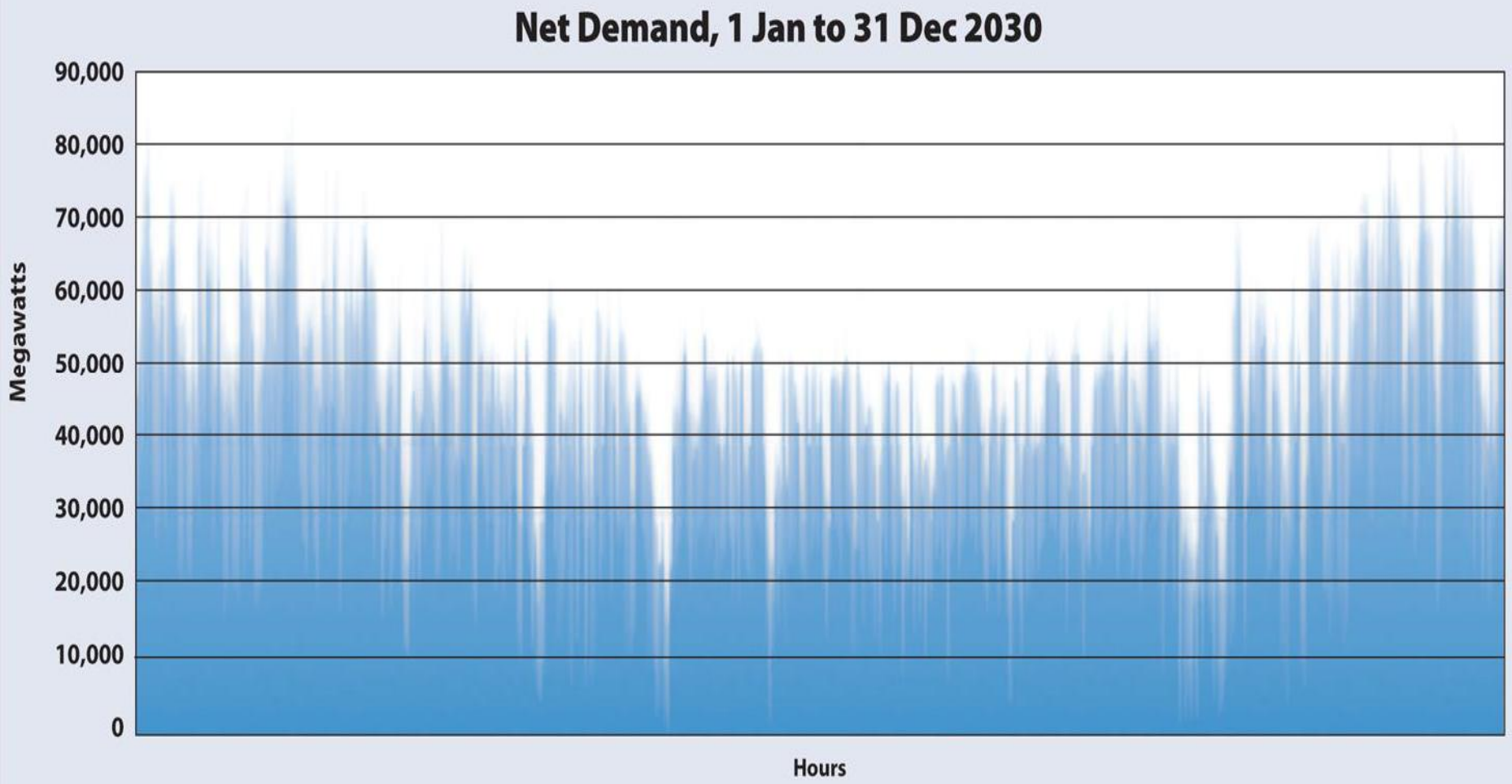
Traditional representation of loads



Loads with more Variable Energy Resources



Future structure

- Interconnected Grid with more DG
  - Enhanced reliability
  - Greater efficiency
  - Lower cost
- Completely distributed grid?
- Role of storage?
- Net-zero energy buildings?
- Carbon policy?

EPRI, *The Integrated Grid,* February 2014, for background

Elements of persuasion

- Reliability
  - the grid will be unstable if . . .
- Economics
  - unnecessary costs will be imposed if . . .
- Fairness
  - these resources/customers will be harmed if . . .
- Policy
  - the public interest will be ignored if . . .

All four = success

Questions?

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