Steve Collier
Director, Smart Grid Strategies

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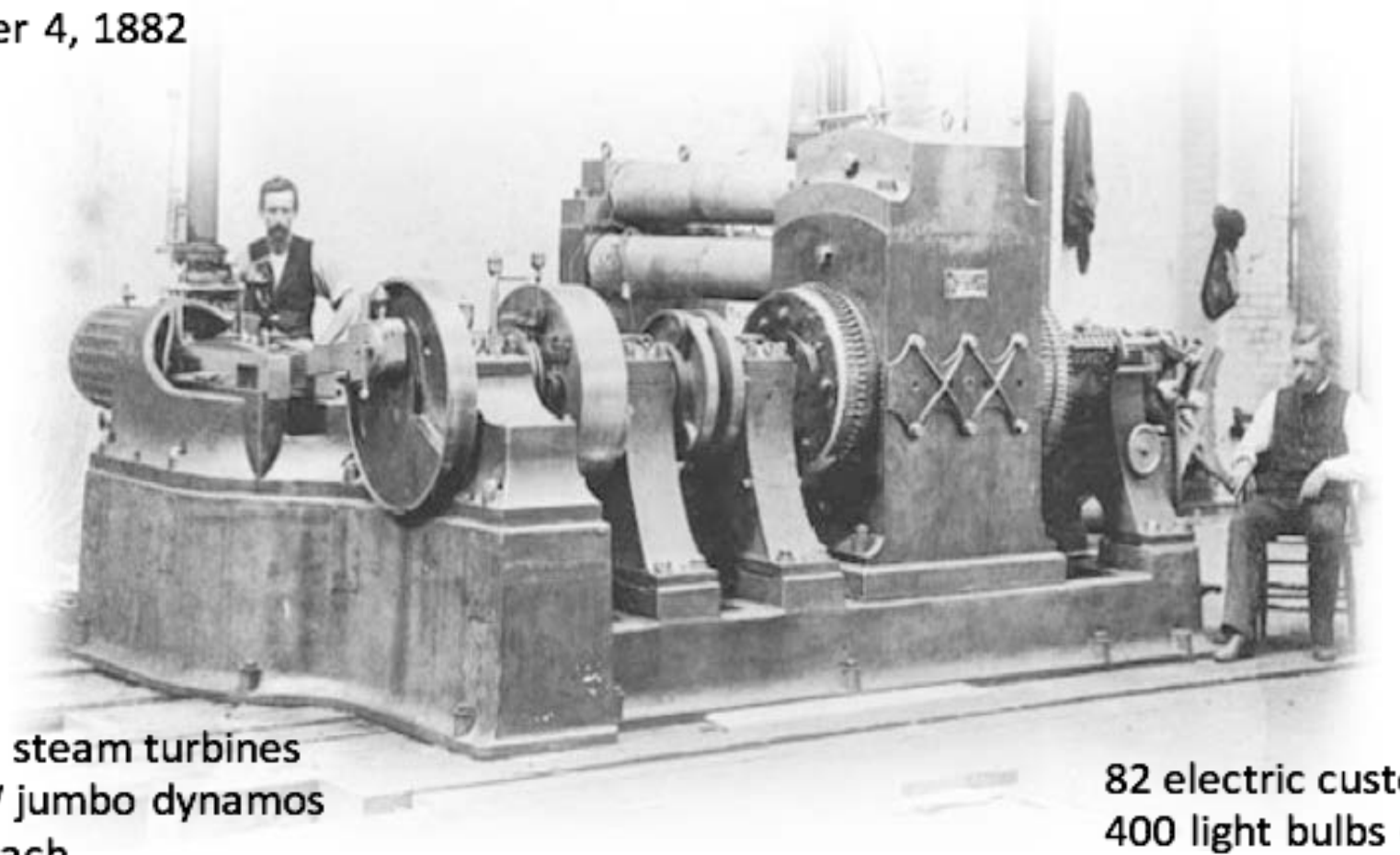
http://bit.ly/MUSCREA

PEARL STREET STATION

255 – 257 Pearl Street
Manhattan, New York
September 4, 1882

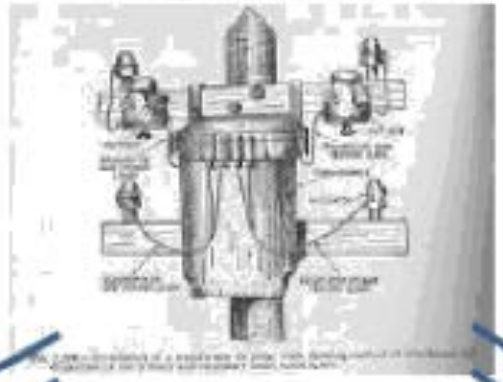


coal fired steam turbines
6 100 kW jumbo dynamos
27 tons each
139,000 btu/kWh
110 Volts DC
100,000 ft of wiring

82 electric customers
400 light bulbs ($1 ea)
50¢ / kWh
Steam customers
district heating

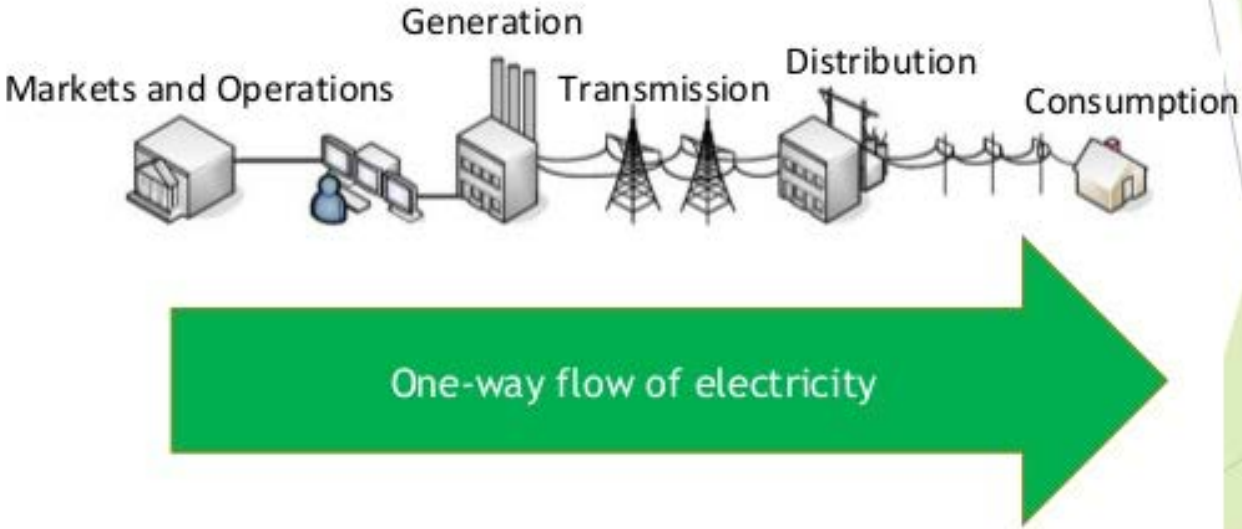
Pearl Street Station

electric pole



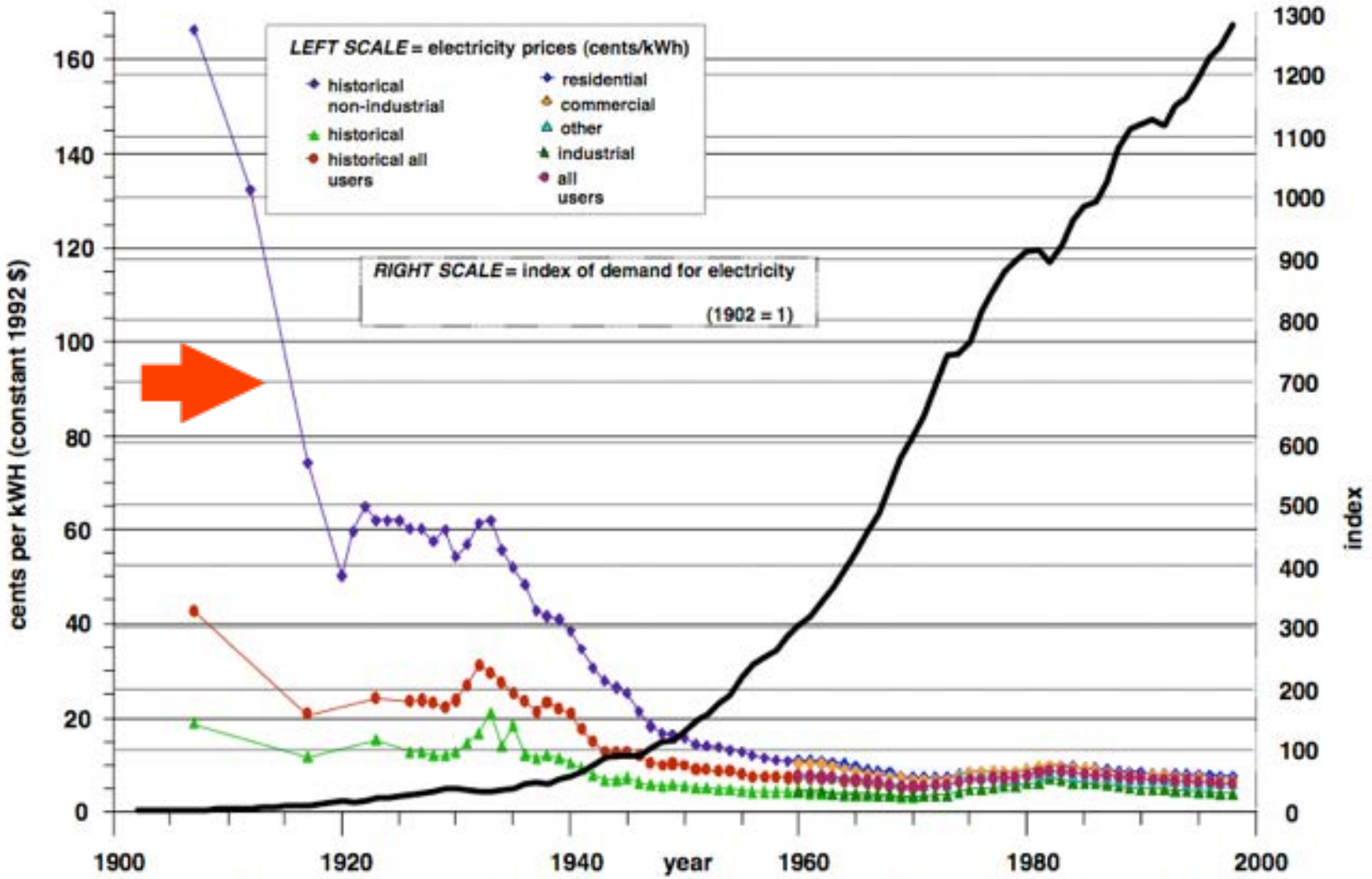
electric light

- Traditional Power Grid:

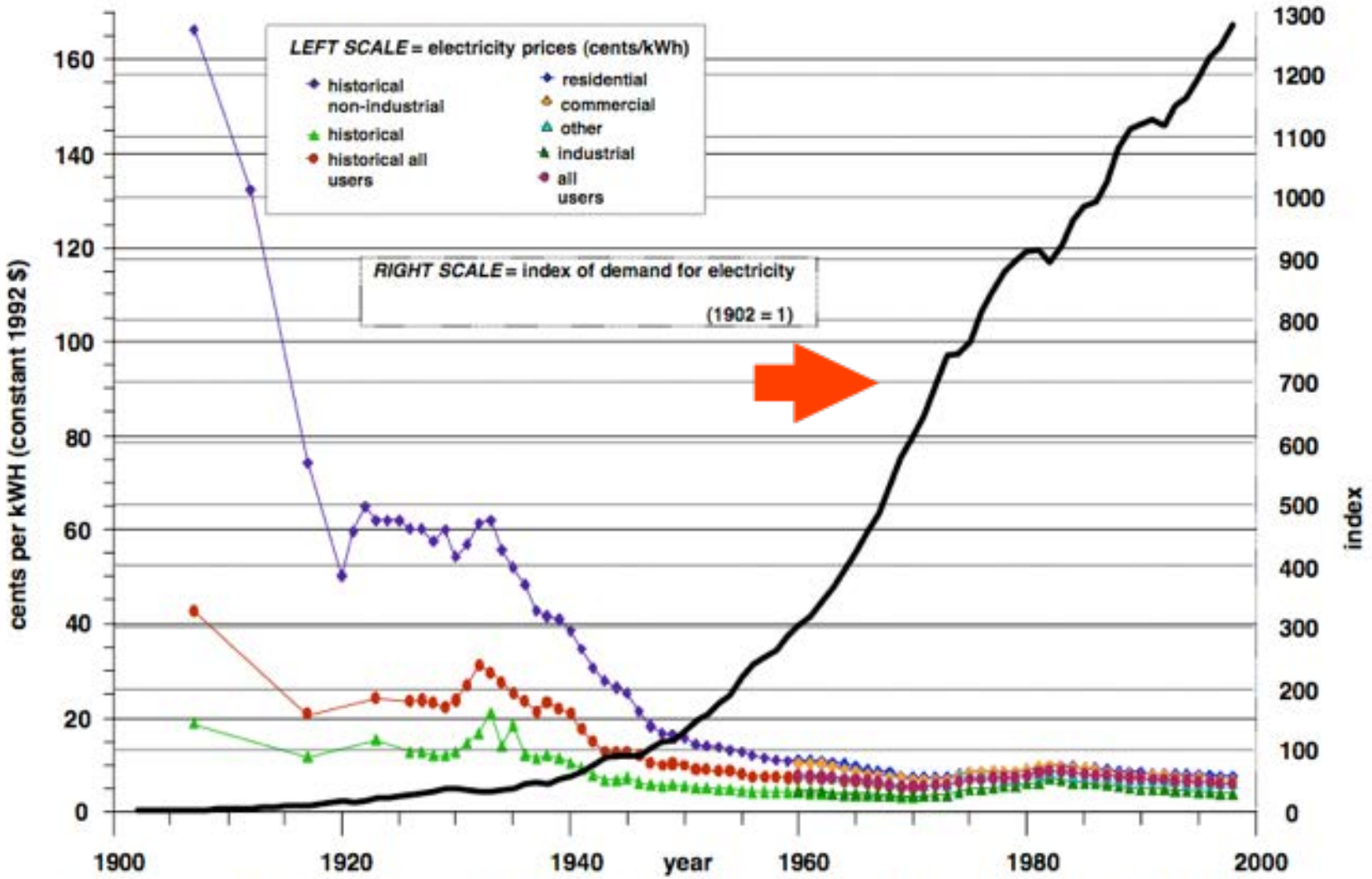


Regulated Monopolies

- **Cost-plus regulation** sets price at per unit explicit costs plus a mark-up for implicit costs
- Used for electricity, telephone and cable
  - Policies vary by state
- Disadvantages
  - High administrative cost
  - Reduced incentive for cost-saving innovation
  - Price is greater than marginal cost



Data sources: 1960-1998: Annual Energy Review Table 8.13 1907-1970: Historical Statistics: Vol 1, Series S116,118, 119



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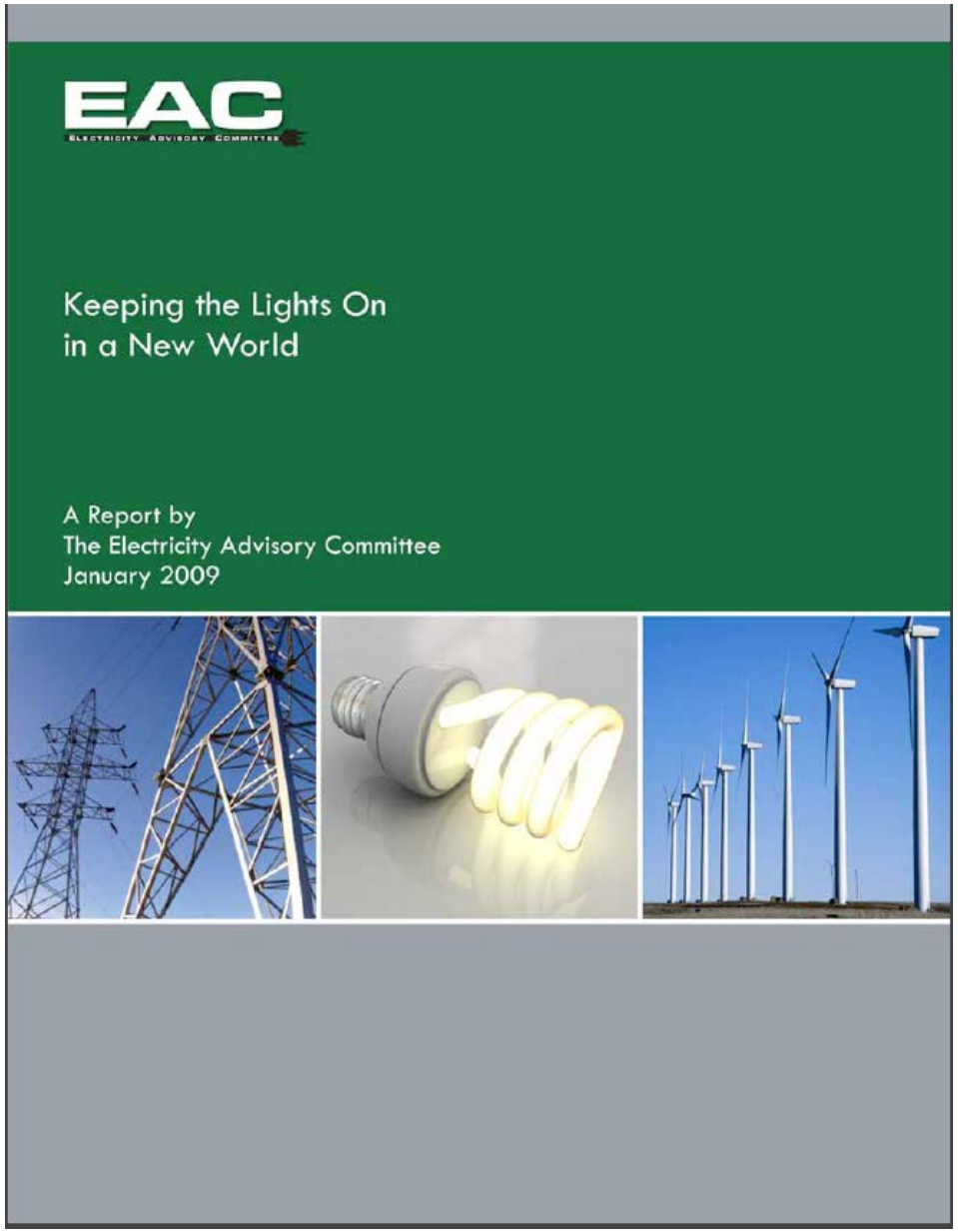
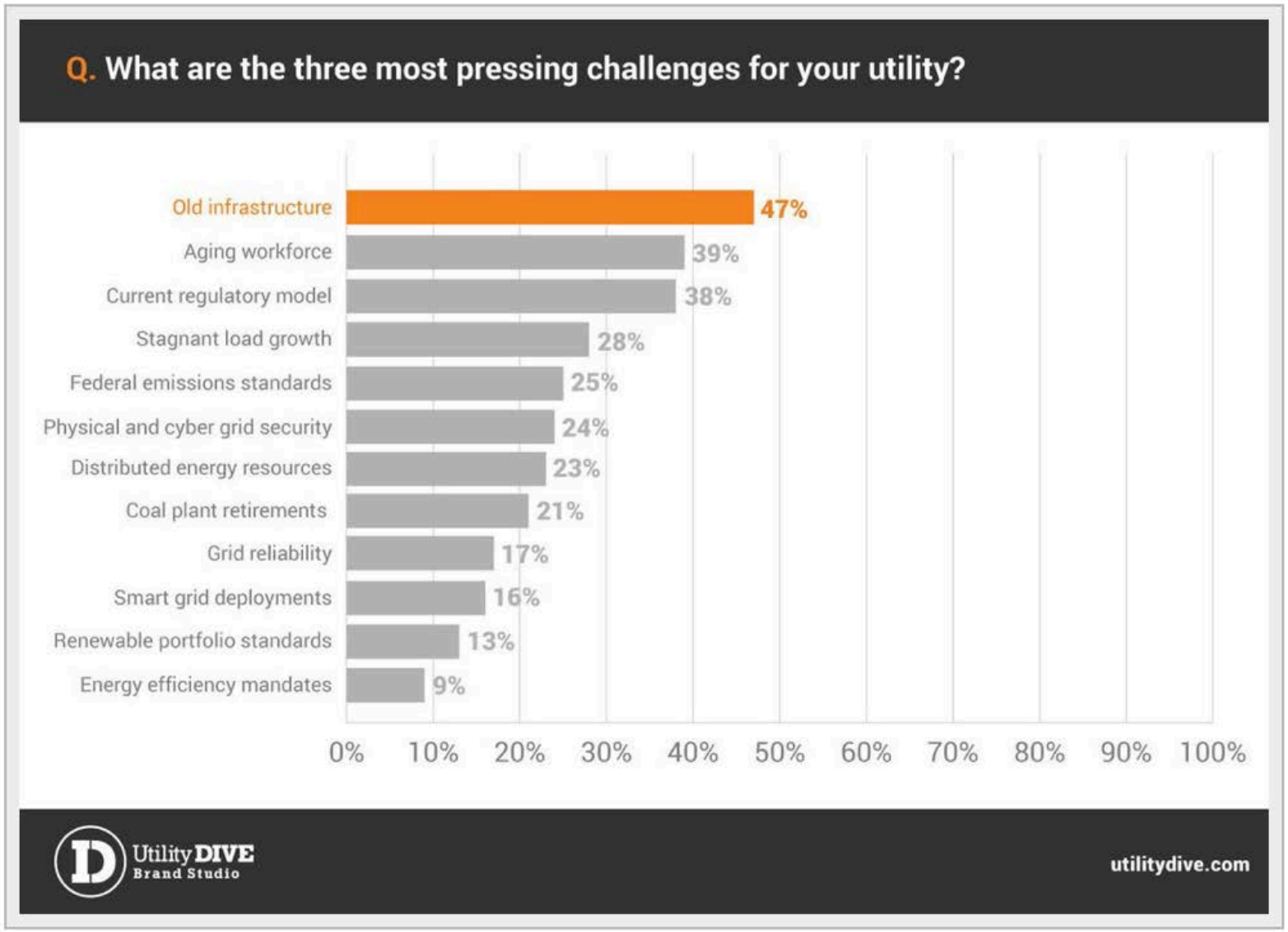


"…the current electric power delivery system infrastructure … will be unable to ensure a reliable, cost-effective, secure, and environmentally sustainable supply of electricity for the next two decades … Much of the electricity supply and delivery infrastructure is nearing the end of its useful life."

ERODING LEGACY FOUNDATIONS

AGING INFRASTRUCTURE



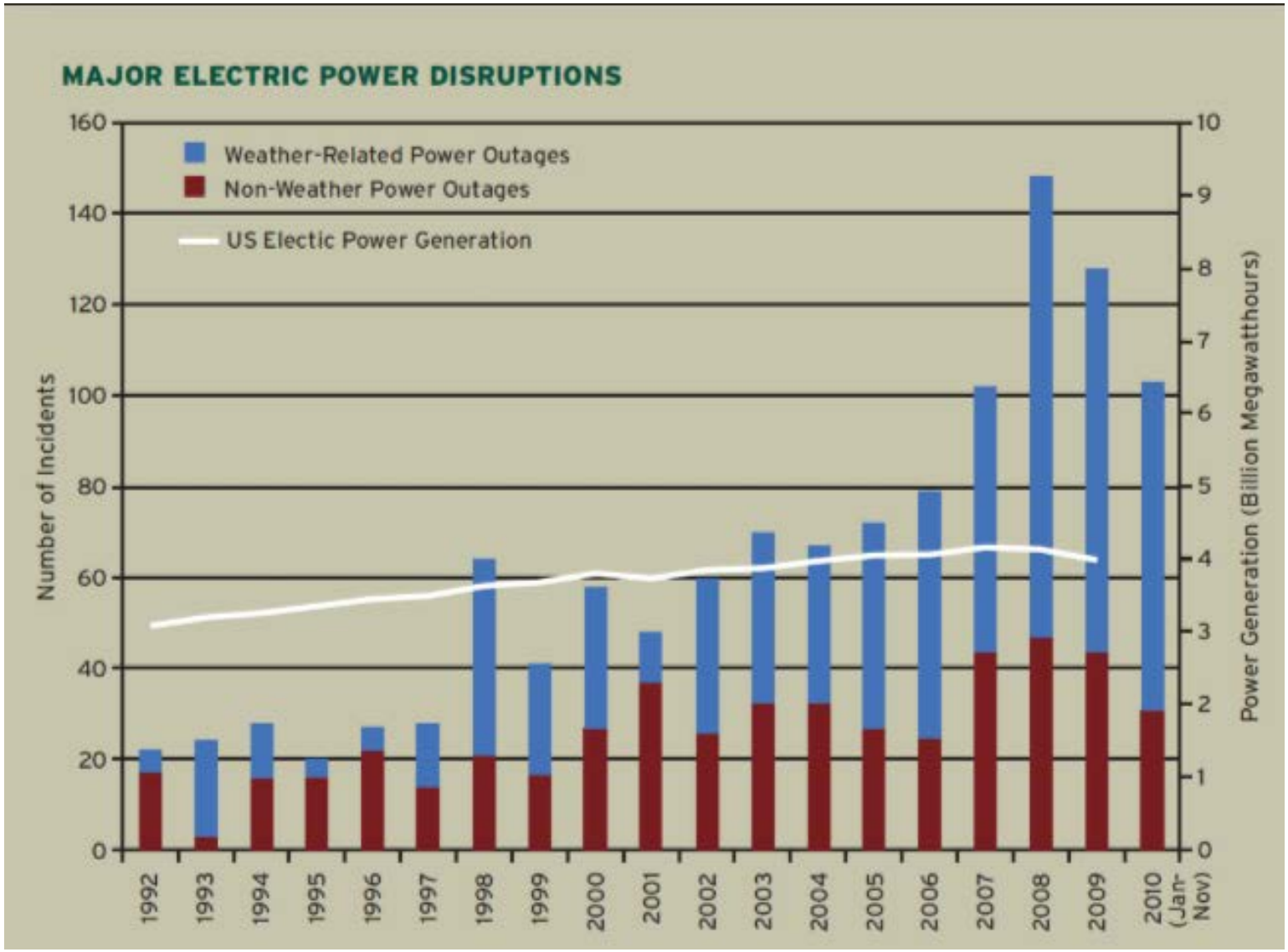
The State of the Electric Utility 2015 survey revealed that aging infrastructure is what troubles industry players most.


In the U.S., the average system age is
40 to 60 years old. At the moment, 25
percent of America's power assets are of
an age in which condition is a concern.

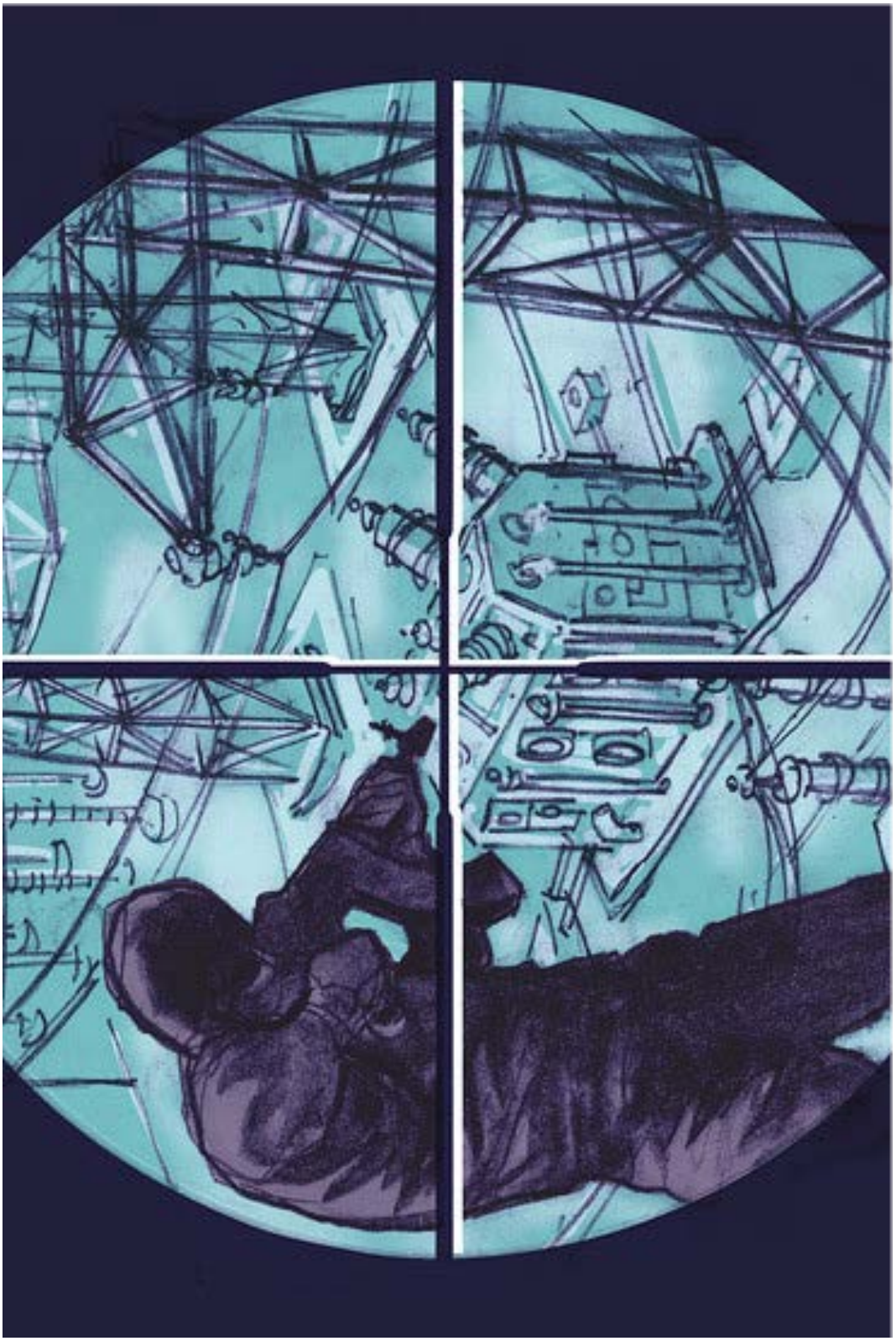
Declining Reliability / Security

According to federal data, the U.S. electric grid loses power 285 percent more often than in 1984, when the data collection effort on blackouts began. That's costing American businesses as much as $150 billion per year, the DOE reported, with weather-related disruptions costing the most per event.

"Each one of these [blackouts] costs tens of hundreds of millions, up to billions, of dollars in economic losses per event," said Massoud Amin, director of the Technological Leadership Institute at the University of Minnesota, who has analyzed U.S. power grid data since it became available in the '80s.

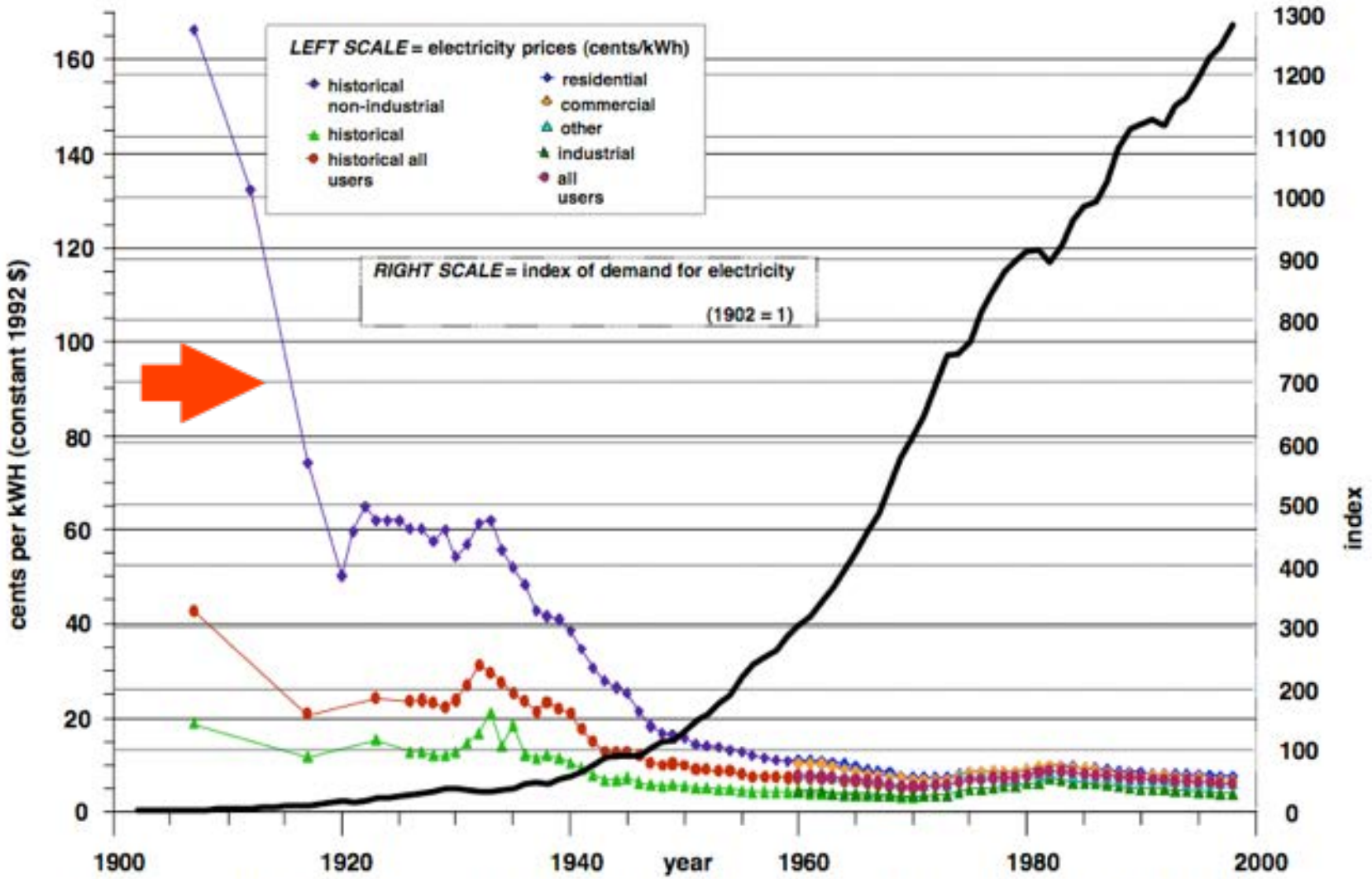

MAJOR ELECTRIC POWER DISRUPTIONS
Weather-Related Power Outages
Non-Weather Power Outages
US Electic Power Generation
Number of Incidents
Power Generation (Billion Megawatthours)
0
20
40
60
80
100
120
140
160
0
1
2
3
4
5
6
7
8
9
10
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010 (Jan-Nov)

New Threats




YOU HAVE BEEN
HACKED !

Rising Costs & Prices



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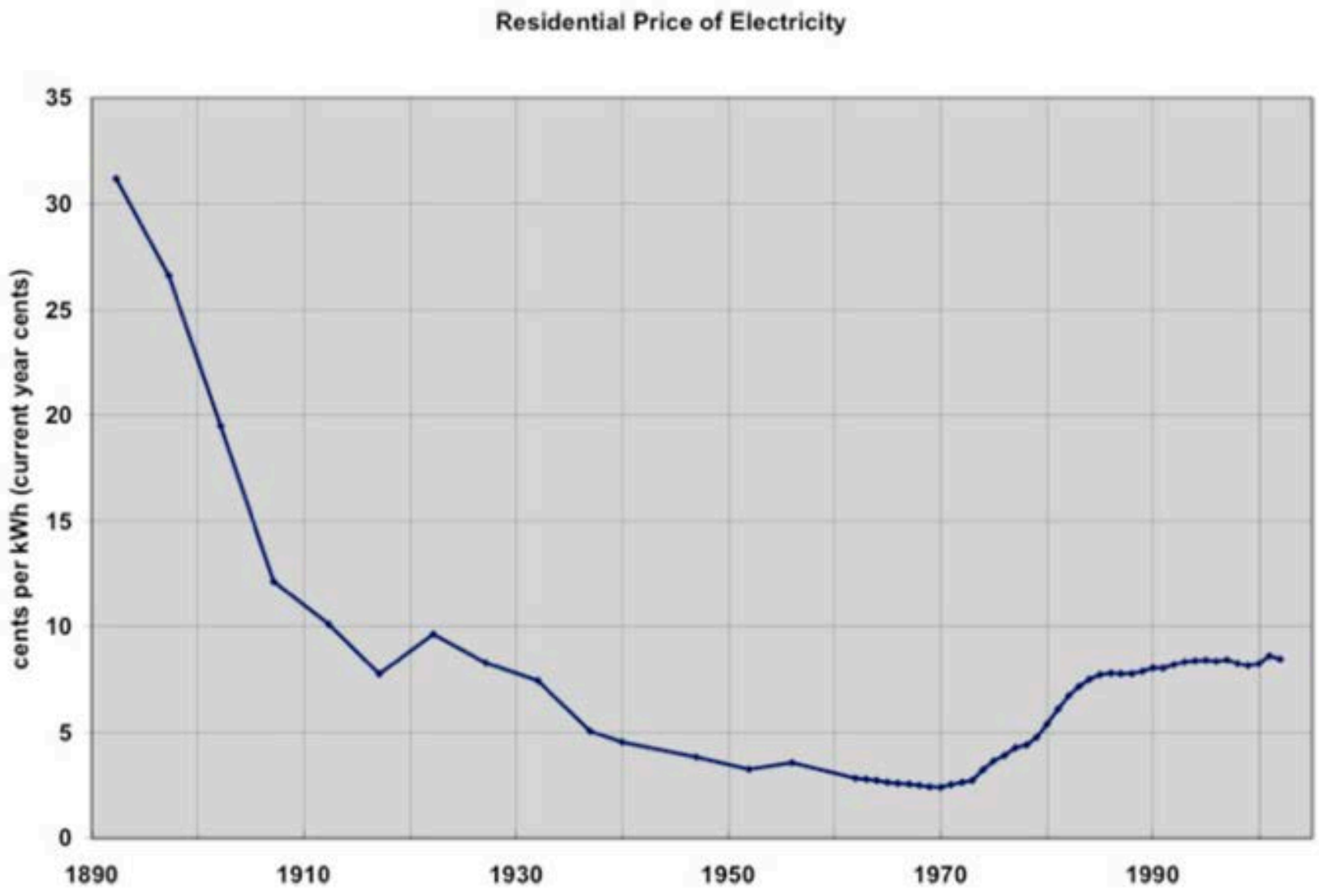
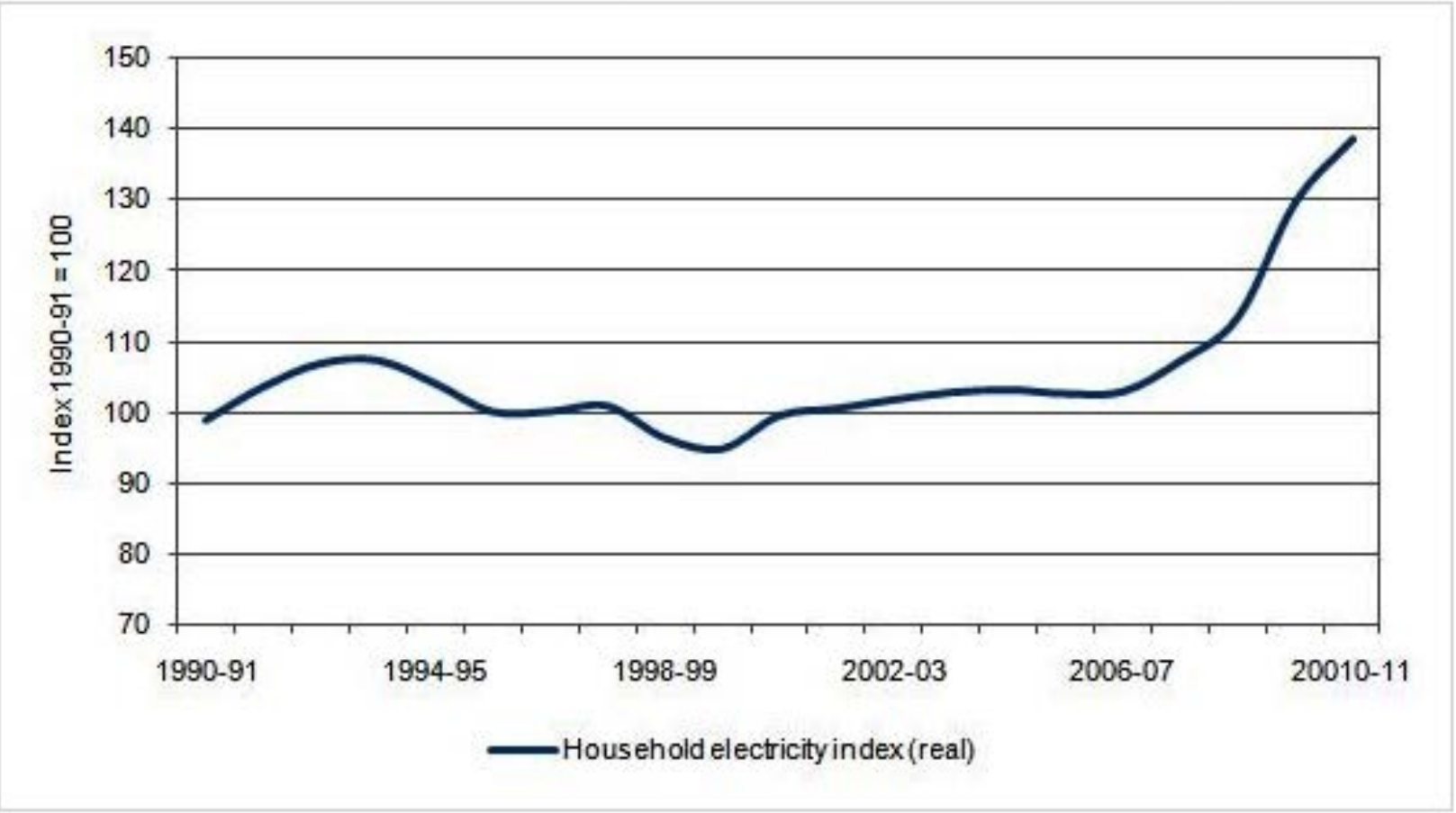
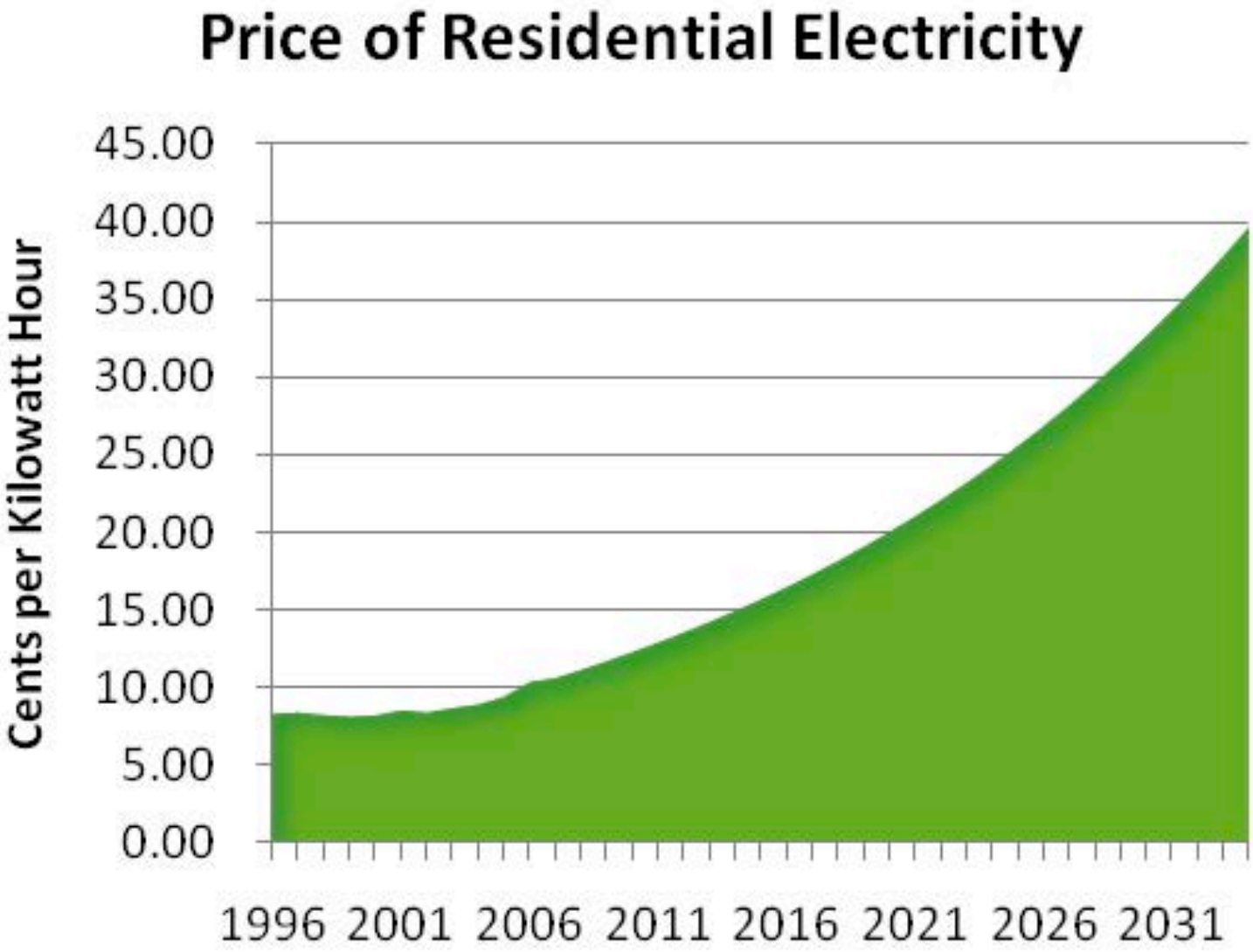


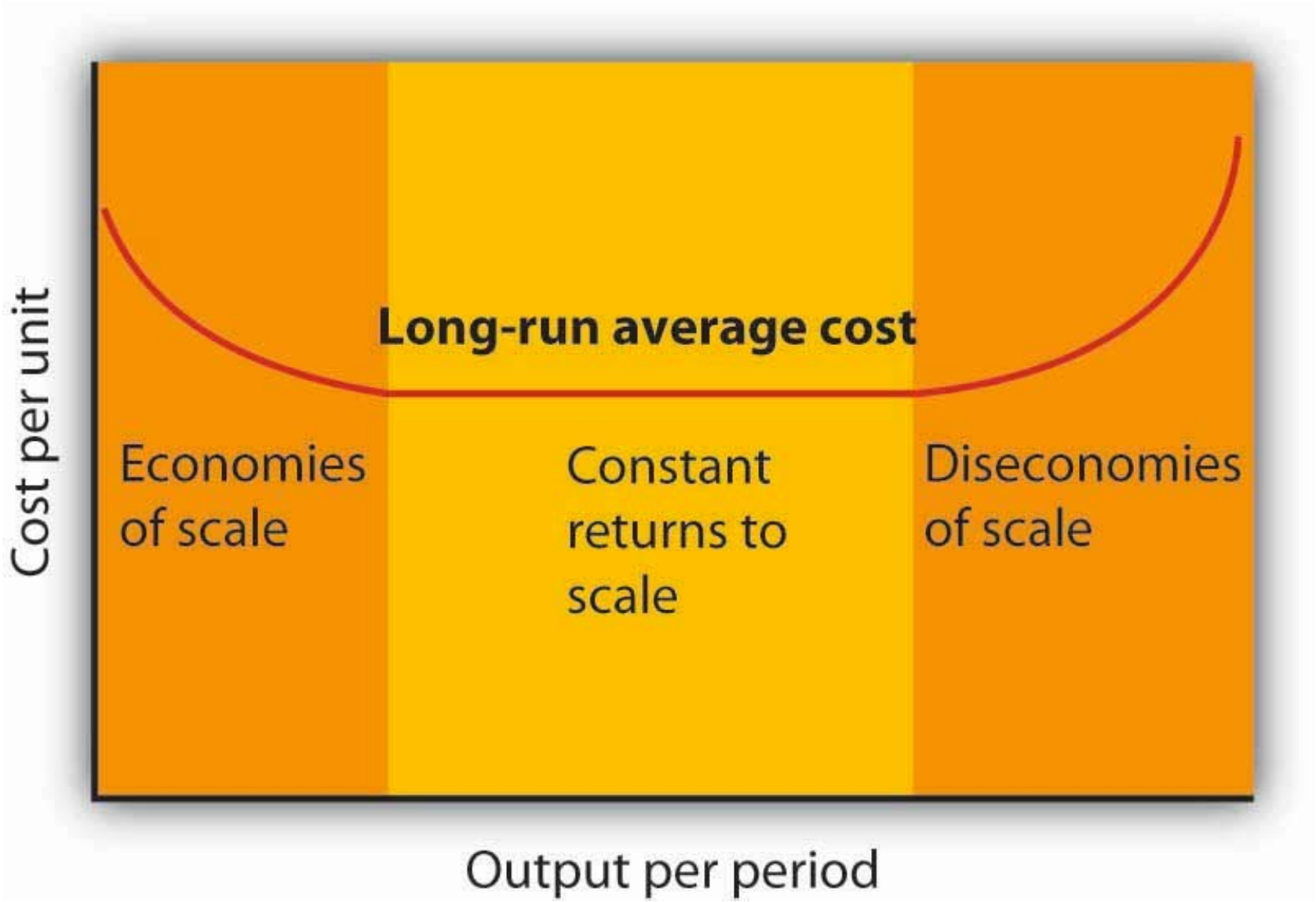
Credit: Solutions. (2005). [The U.S. Electric Power Sector and Climate Change Mitigation](). Morgan, G, Apt, J., Lave, L.

(constant 100 would mean electricity prices rising at same rate as other prices)



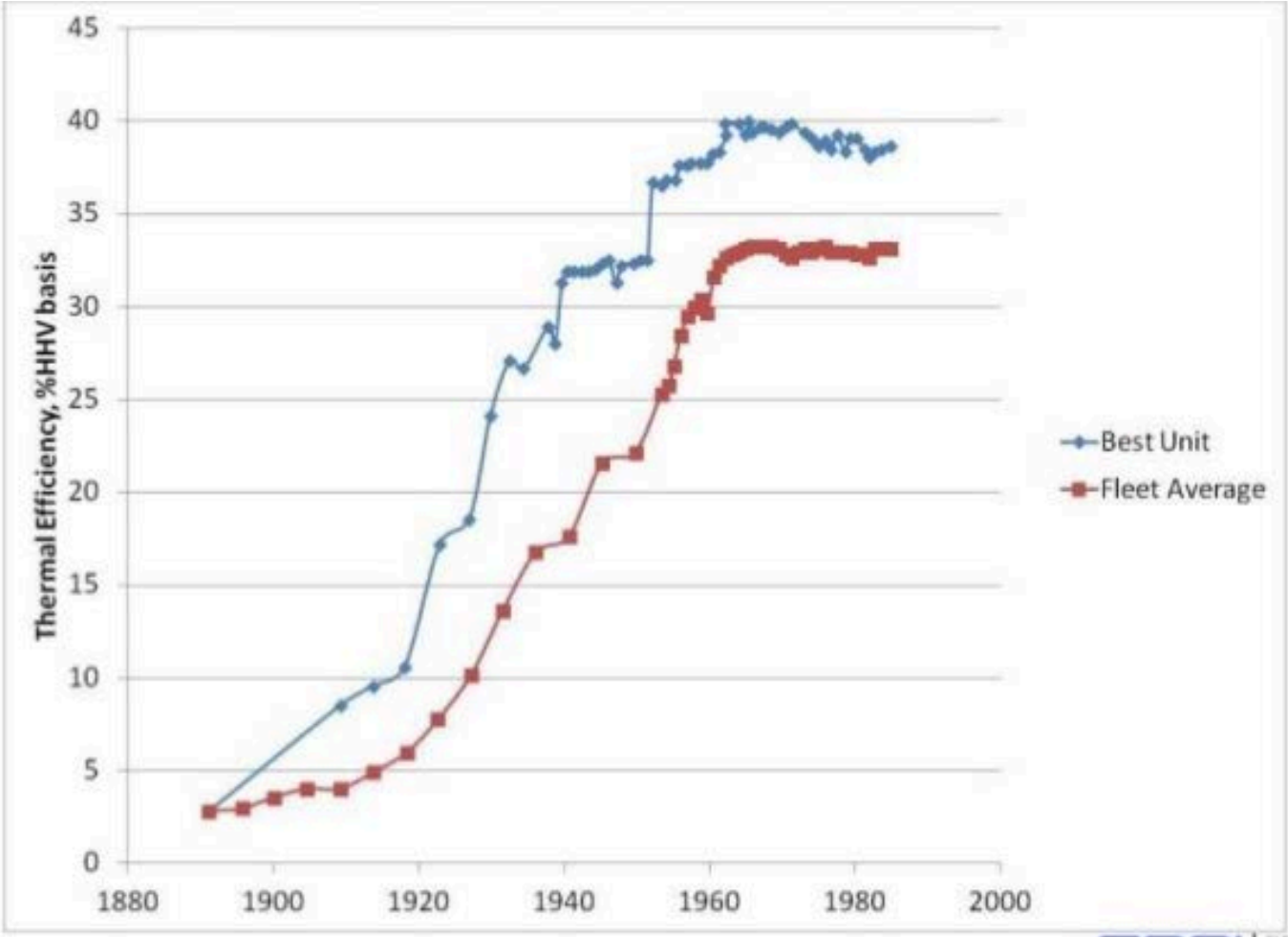


Source: US Department of Energy

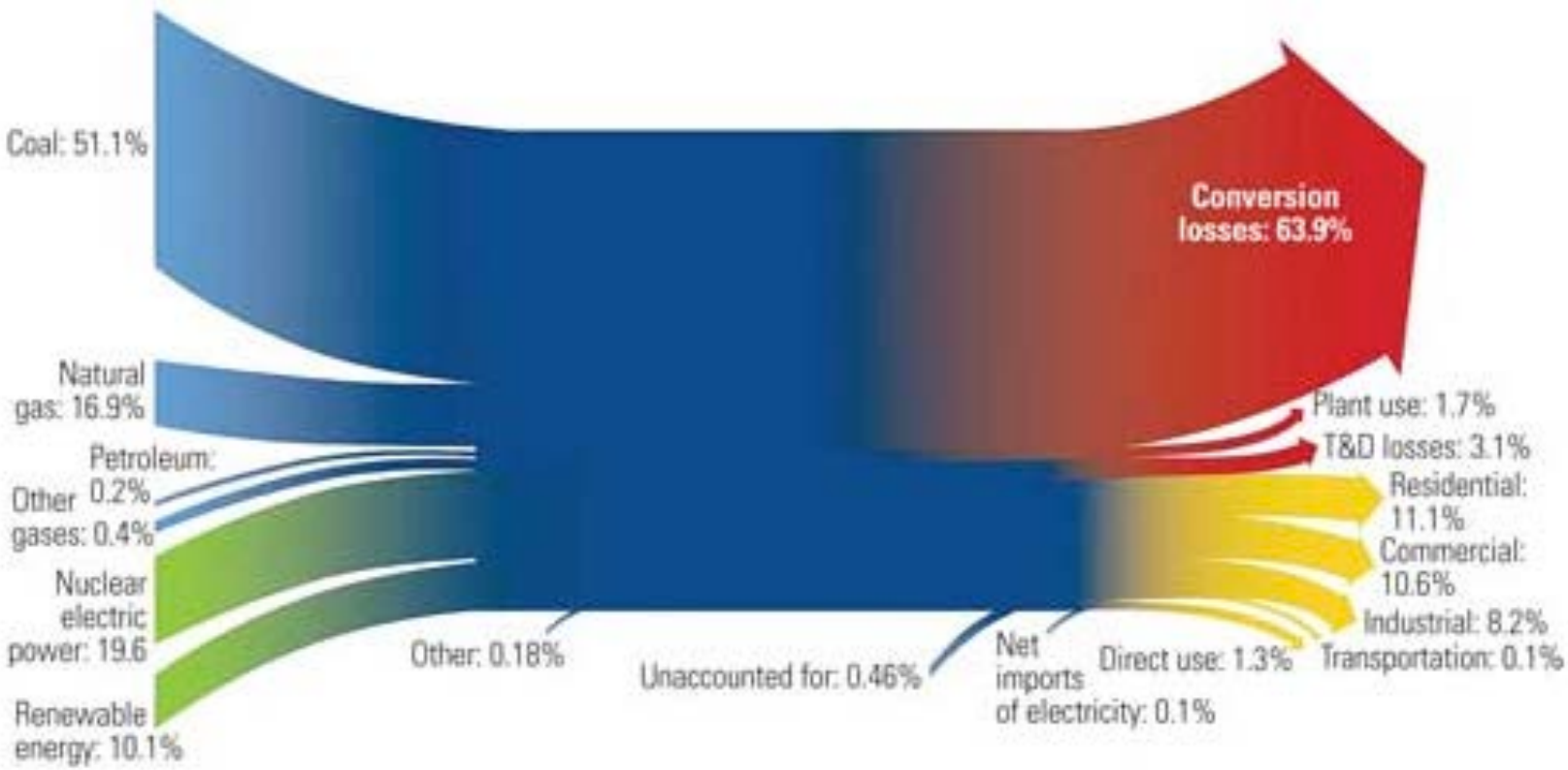

Long-run average cost
Economies of scale
Constant returns to scale
Diseconomies of scale
Cost per unit
Output per period

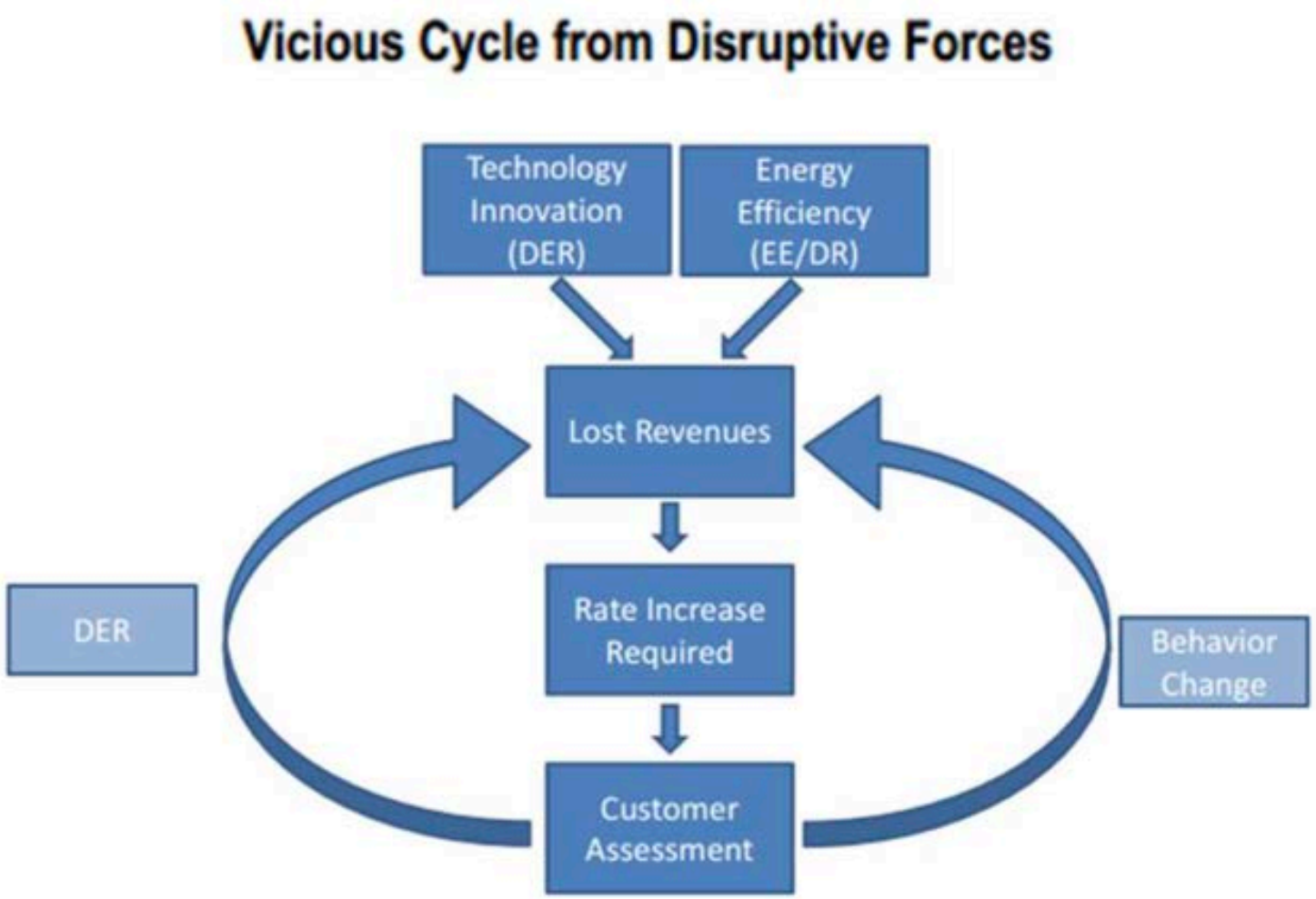

RISK

- Construction
- Regulatory
- Operational
- Market
  - Price
  - Preference



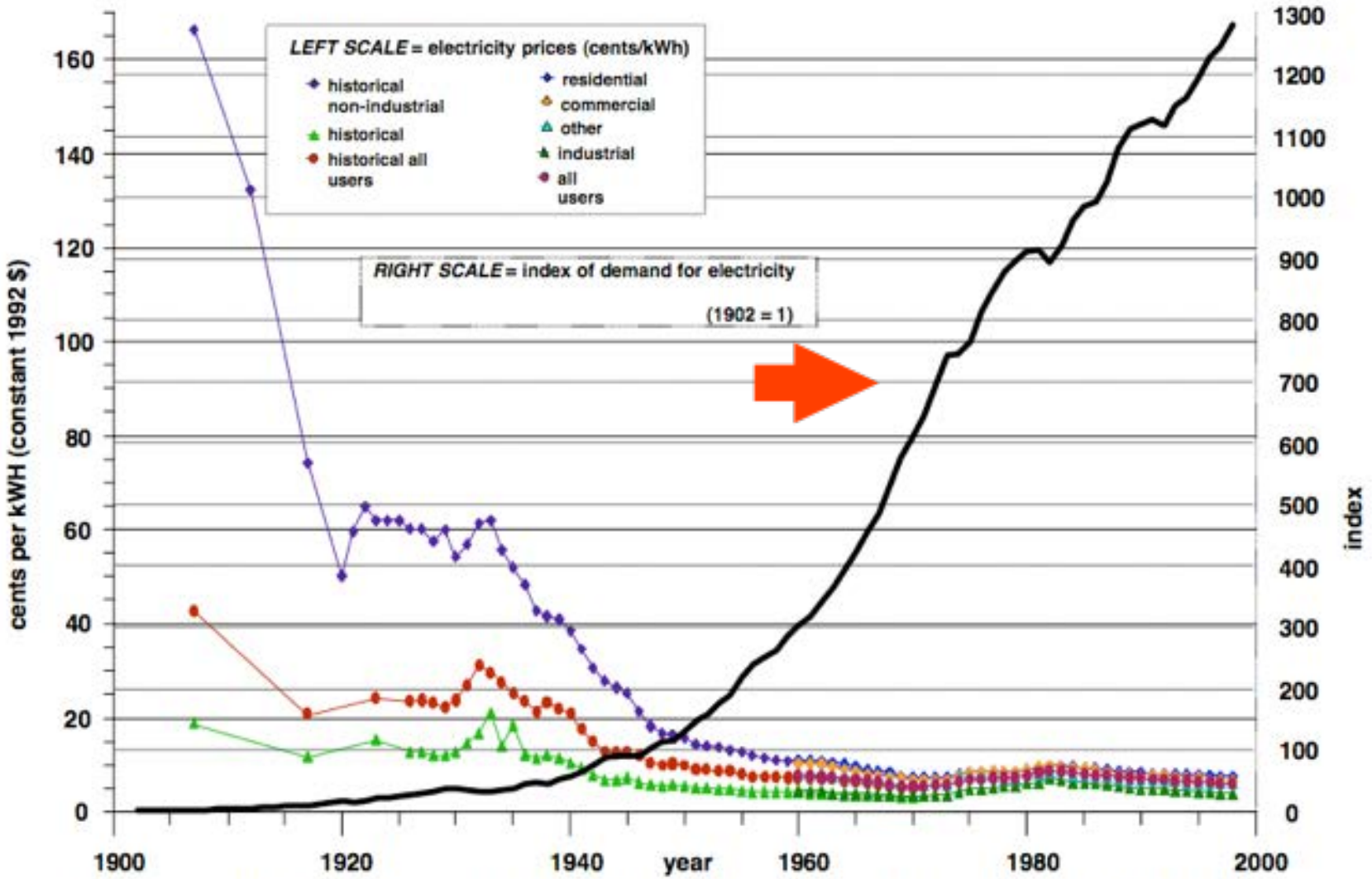
EPRI ELECTRIC POWER RESEARCH INSTITUTE


Coal: 51.1%
Natural gas: 16.9%
Petroleum: 0.2%
Other gases: 0.4%
Nuclear electric power: 19.6
Renewable energy: 10.1%
Other: 0.18%
Unaccounted for: 0.46%
Net imports of electricity: 0.1%
Conversion losses: 63.9%
Plant use: 1.7%
T&D losses: 3.1%
Residential: 11.1%
Commercial: 10.6%
Industrial: 8.2%
Transportation: 0.1%
Direct use: 1.3%

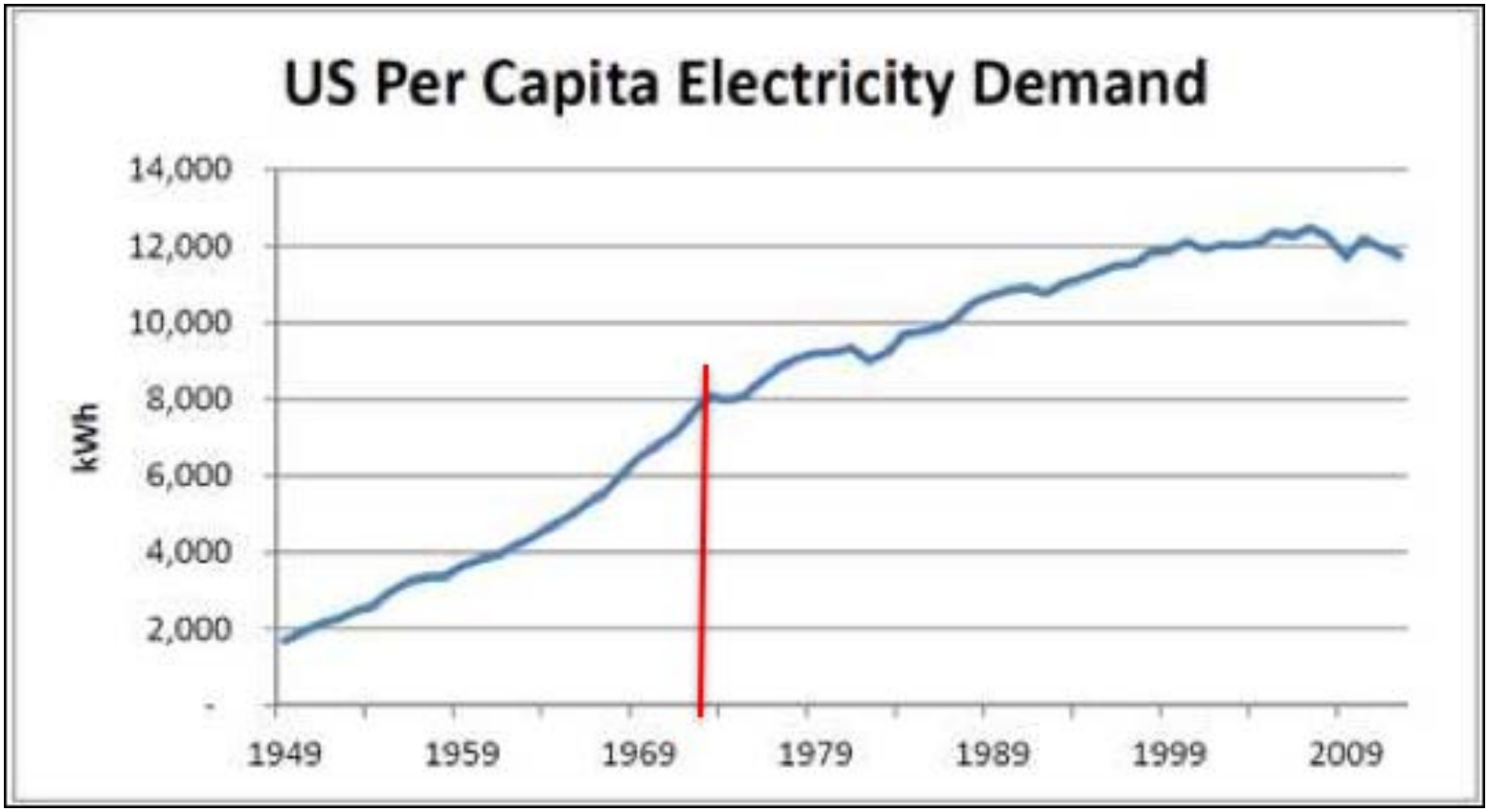


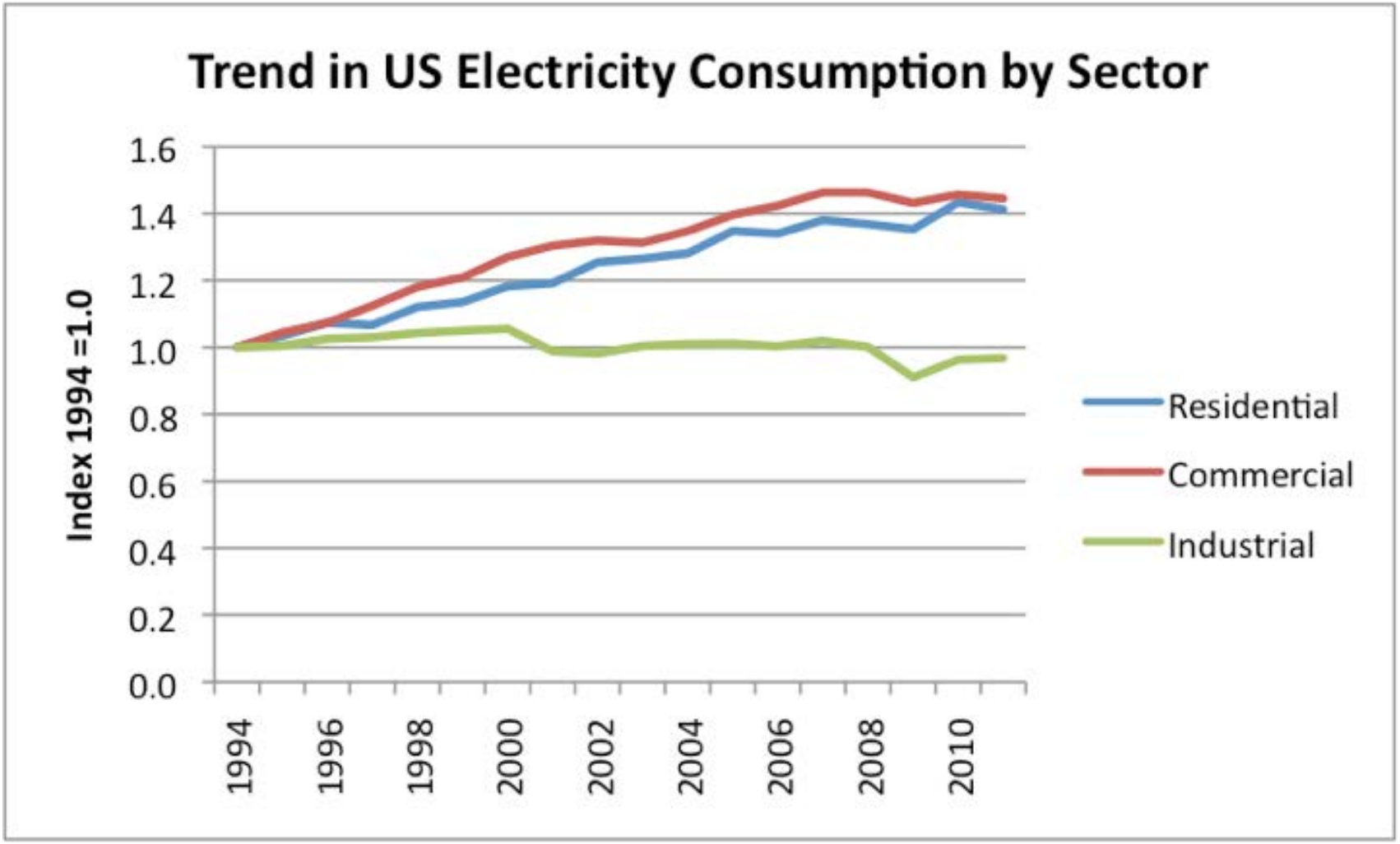
The threat of the "utility death spiral" is pushing companies to rethink their rate structures, often with controversial consequences. *Credit: Edison Electric Institute's "Disruptive Challenges"*

Diminishing Growth In Electric Energy Consumption



Data sources: 1960-1998: Annual Energy Review Table 8.13 1907-1970: Historical Statistics: Vol 1, Series S116,118, 119


US Per Capita Electricity Demand
kWh
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
1949
1959
1969
1979
1989
1999
2009


Trend in US Electricity Consumption by Sector
Index 1994 =1.0
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1994
1996
1998
2000
2002
2004
2006
2008
2010
Residential
Commercial
Industrial

ENERGY

EFFICIENCY & CONSERVATION

✓ Same output for lesser energy.

Efficiency

By buying efficient appliances.

✓ Reduce consumption or stop wastage to save energy.

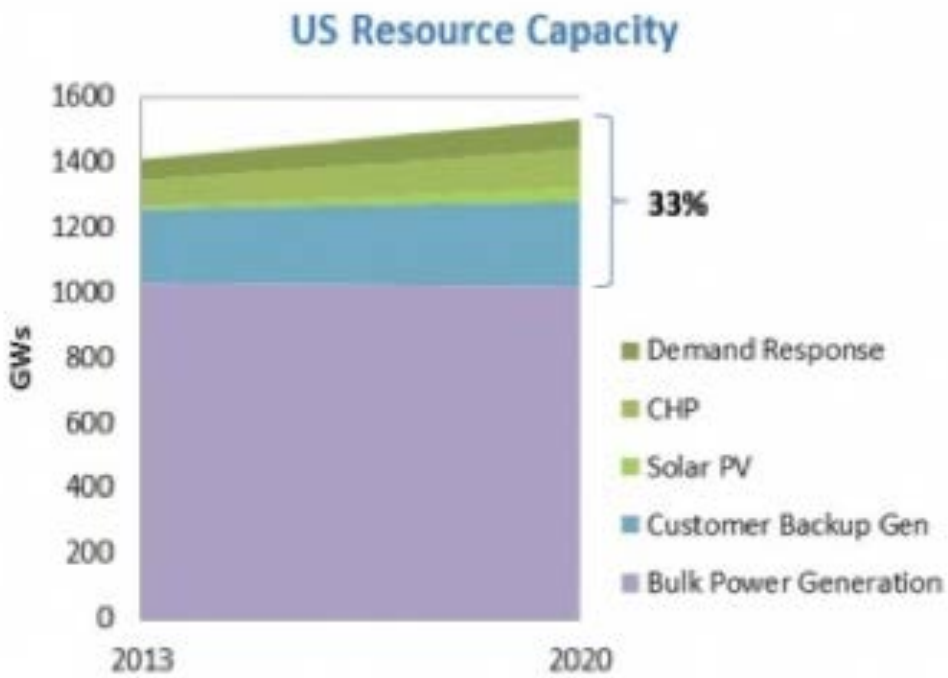
Conservation

By stopping wastage and using appliances properly.

Both Save Energy and Money

DER may reach 33% of Installed US Capacity by 2020

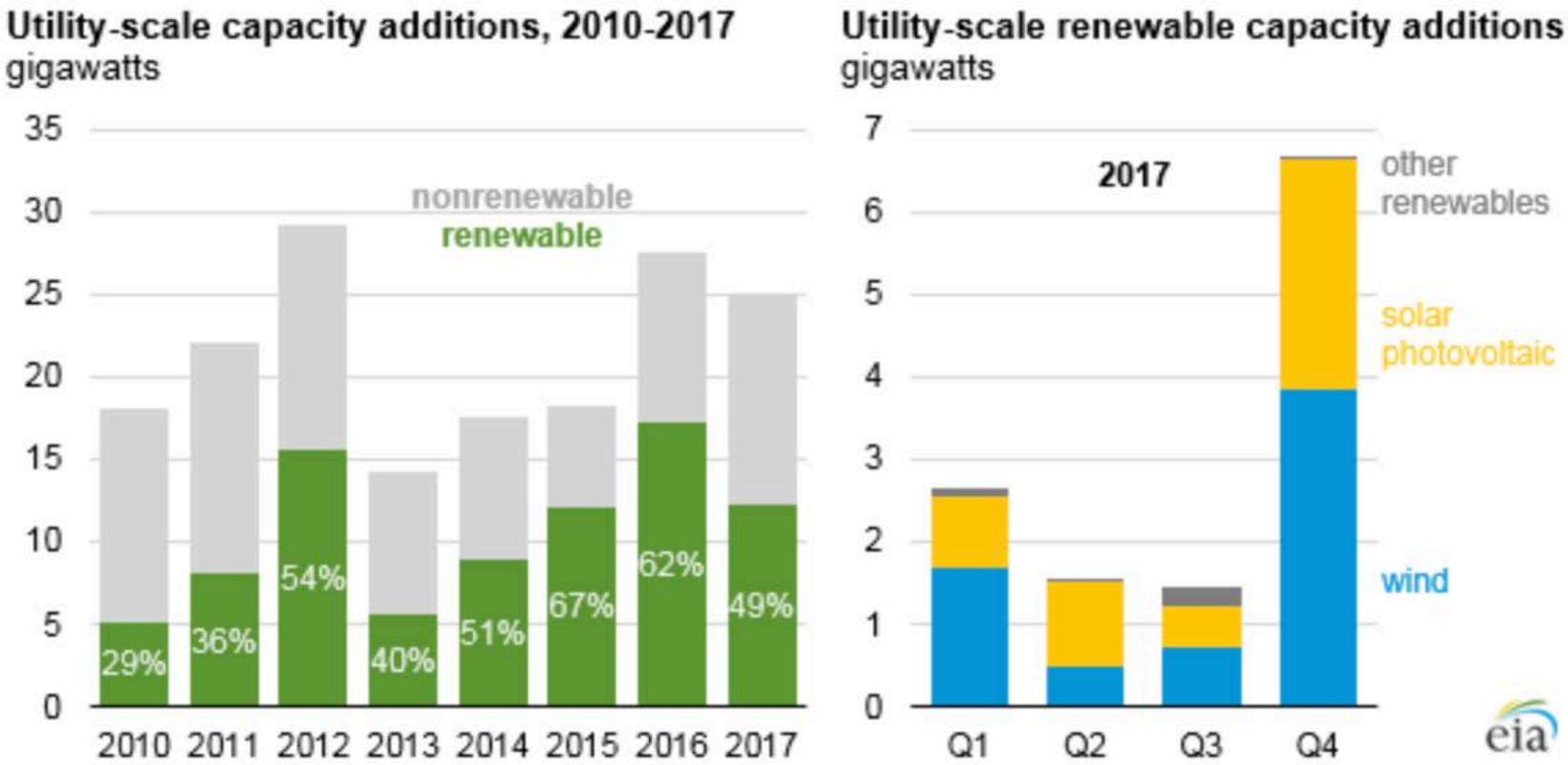
Effectively all incremental growth in capacity will come from customers



Sources: EIA, EPA, DOE, FERC, Carnegie Mellon, GlobalData

Backup Generation:	**240 GW**
CHP:	**122 GW**
Demand Response:	**90 GW**
Solar PV:	**40 GW**
Other DG:	**15 GW**
Dist. Storage:	**3 GW**
Potential DER Total:	***500 GW***

Nearly half of utility-scale capacity installed in 2017 came from renewables



Source: U.S. Energy Information Administration, Form EIA-860M, *Preliminary Monthly Electric Generator Inventory*

Netting all additions and retirements

Renewables accounted for
~95% !!!

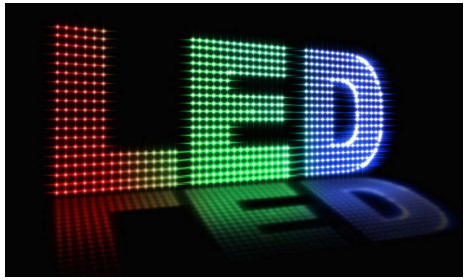
Eroding Monopoly

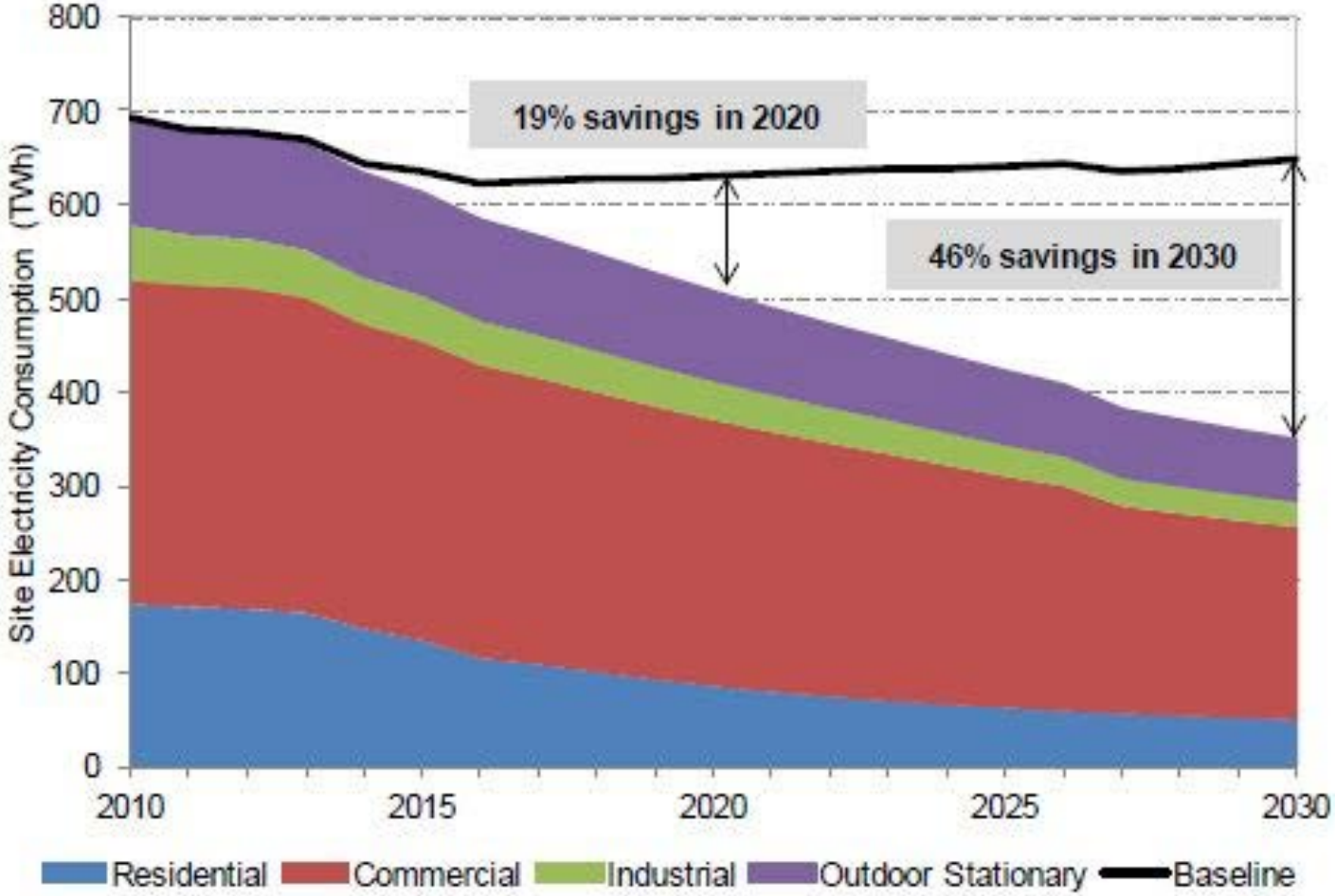
FORM AL DEREGULATION

DEFACTO DEREGULATION


DISTRIBUTED ENERGY
RESOURCES

Conservation & Energy Efficiency


LED

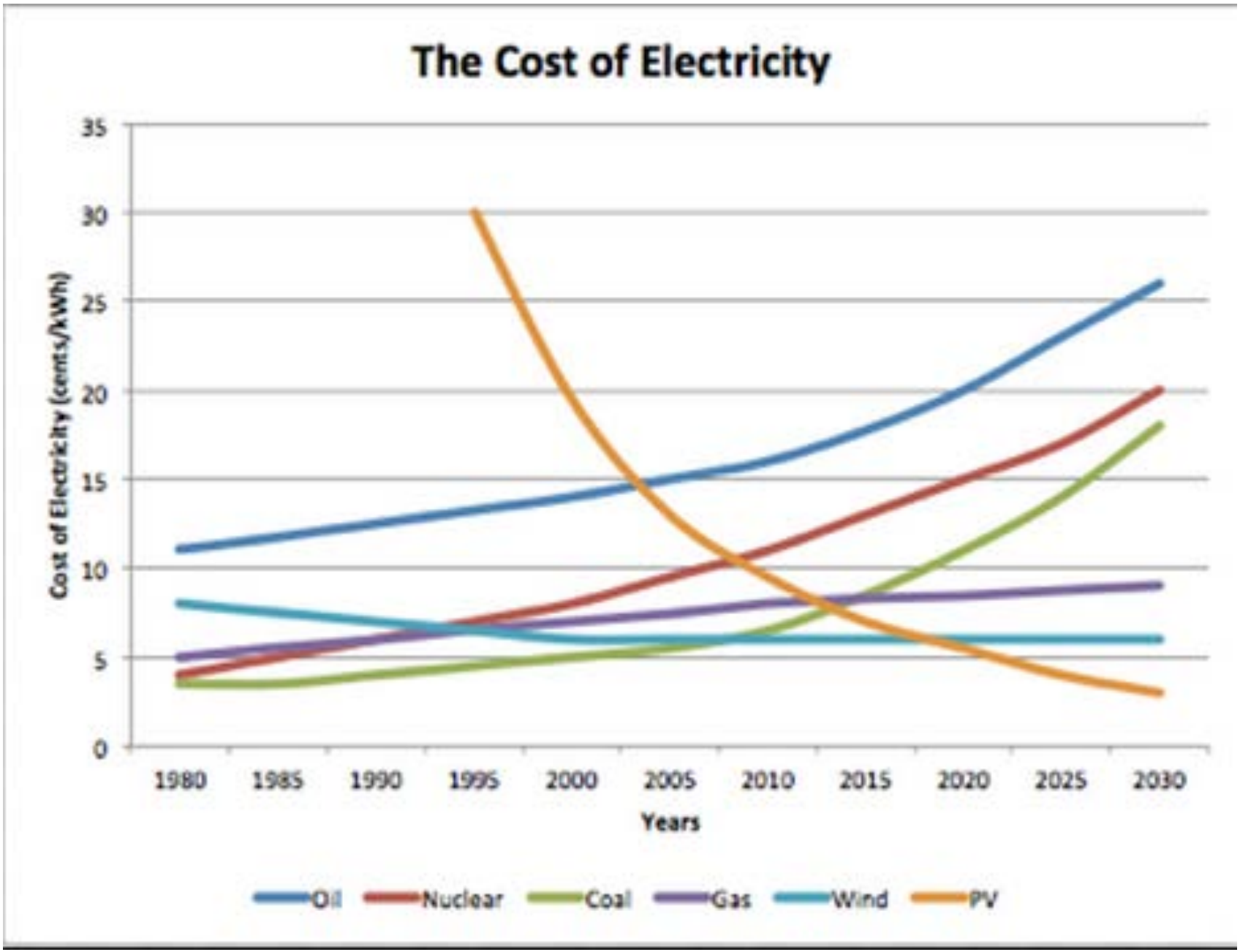

Site Electricity Consumption (TWh)
800
700
600
500
400
300
200
100
0
2010
2015
2020
2025
2030
19% savings in 2020
46% savings in 2030
Residential
Commercial
Industrial
Outdoor Stationary
Baseline

Energy Management Systems

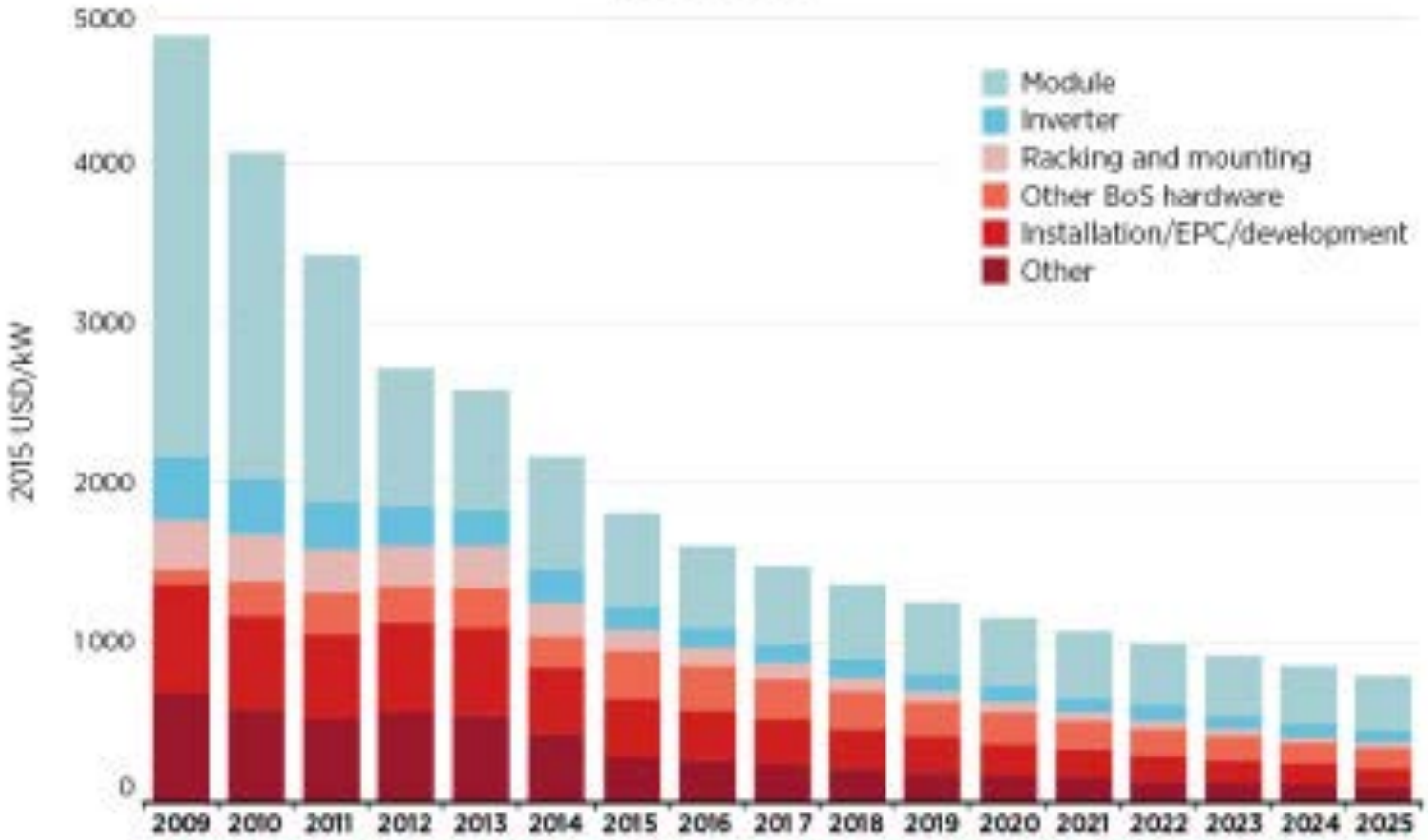
become

Non-Utility Virtual Power Plants


nest
67
IN 20 MIN
72


The Cost of Electricity
Cost of Electricity (cents/kWh)
35
30
25
20
15
10
5
0
1980
1985
1990
1995
2000
2005
2010
2015
2020
2025
2030
Years
Oil
Nuclear
Coal
Gas
Wind
PV

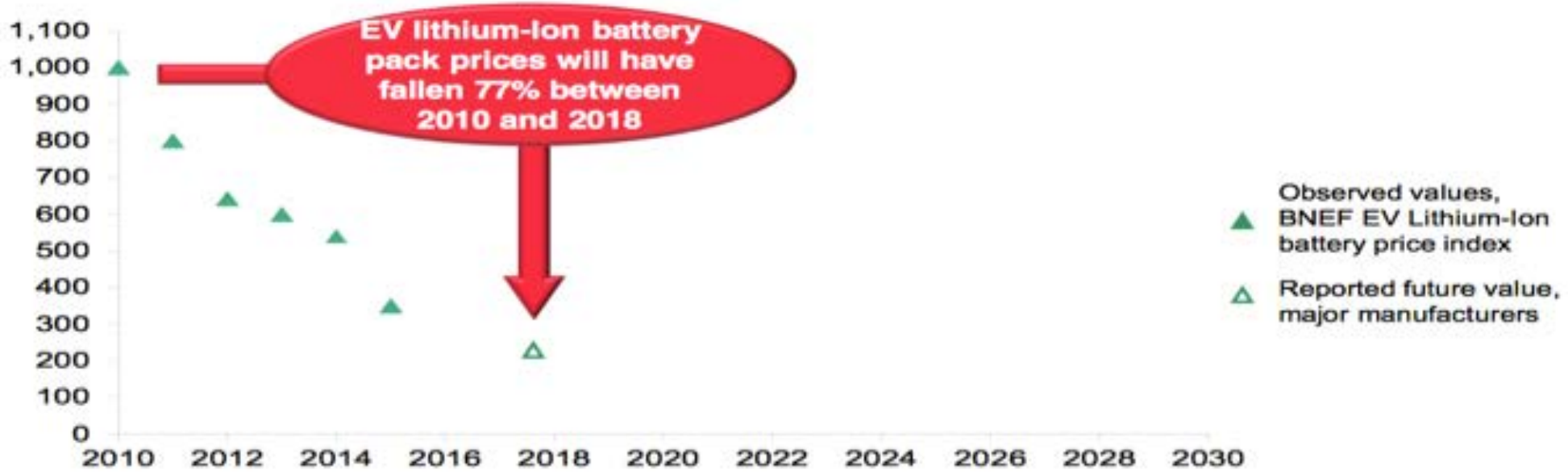
Utility-scale solar PV: Global weighted average of total installed costs, 2009-2025




Nuclear Power Plant
Factories
Thermal Power Plant
Electric Vehicle
Smart Grid
City & Buildings
Wind Power Plant
Smart Houses
Solar Power Plant

EV LITHIUM-ION BATTERY PACK PRICE
($/KWh)

Bloomberg
NEW ENERGY FINANCE



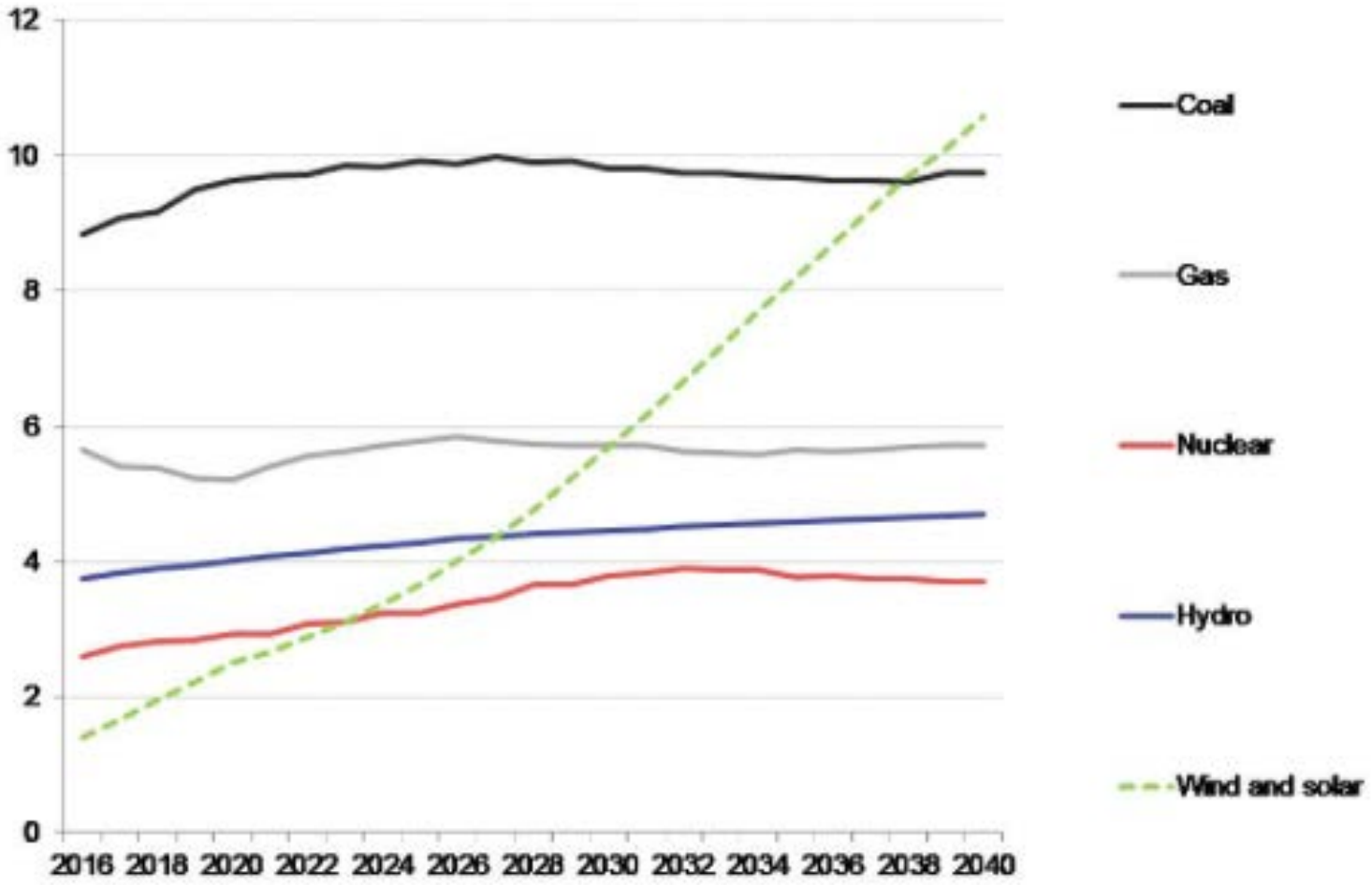
Note: Forecast range based on a learning rate of 14-20%. EV cost parity is calculated on an unsubsidised total cost of ownership (TCO) basis. Date range reflects cross over with different vehicle classes in the US.

Source: Bloomberg New Energy Finance. EV lithium-ion battery price index

Michael Liebreich
State of the Industry Keynote
BNEF Global Summit 2017

https://about.bnef.com/blog/liebreich-state-industry-keynote-bnef-global-summit-2017/

Annual electricity output by the major generating technologies, 2016-40, thousand TWh



“Wind and solar are set to surge to almost “50 by 50” – 50% of world generation by 2050 – on the back of precipitous reductions in cost, and the advent of cheaper and cheaper batteries that will enable electricity to be stored and discharged to meet shifts in demand and supply. Coal shrinks to just 11% of global electricity generation by 2050.”

- https://about.bnef.com/new-energy-outlook/

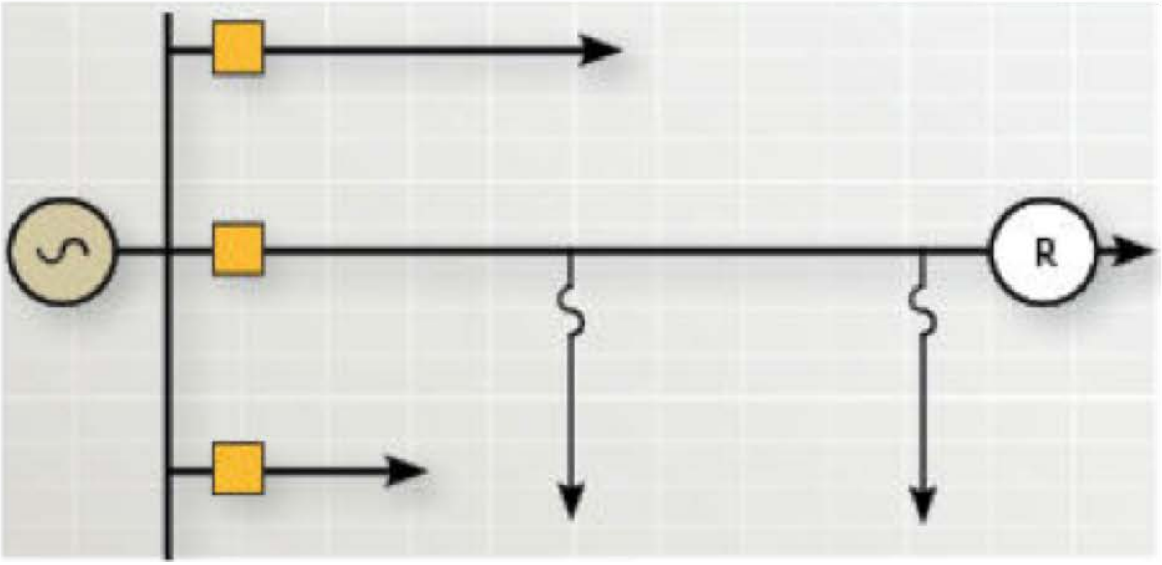
Solar With Batteries Cheaper Than Gas in Parts of U.S. Southwest

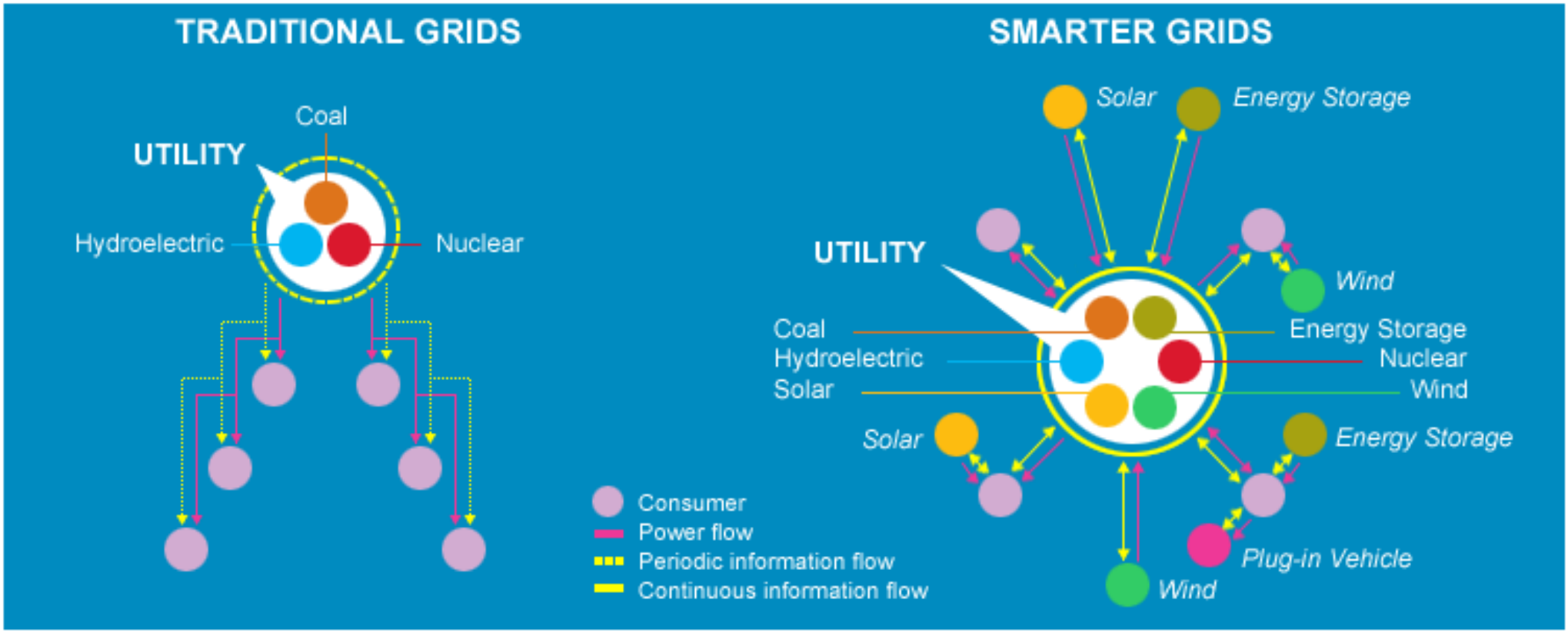
bloomberg.com

https://www.bloomberg.com/news/articles/2018-09-17/solar-with-batteries-cheaper-than-gas-in-parts-of-u-s-southwest

GRID2DGE

LEGACY DISTRIBUTION SYSTEM MODEL




TRADITIONAL GRIDS
UTILITY
Coal
Hydroelectric
Nuclear
SMARTER GRIDS
Solar
Energy Storage
UTILITY
Wind
Coal
Energy Storage
Hydroelectric
Nuclear
Solar
Wind
Solar
Energy Storage
Plug-in Vehicle
Wind
Consumer
Power flow
Periodic information flow
Continuous information flow

DER DISTRIBUTION SYSTEM MODEL

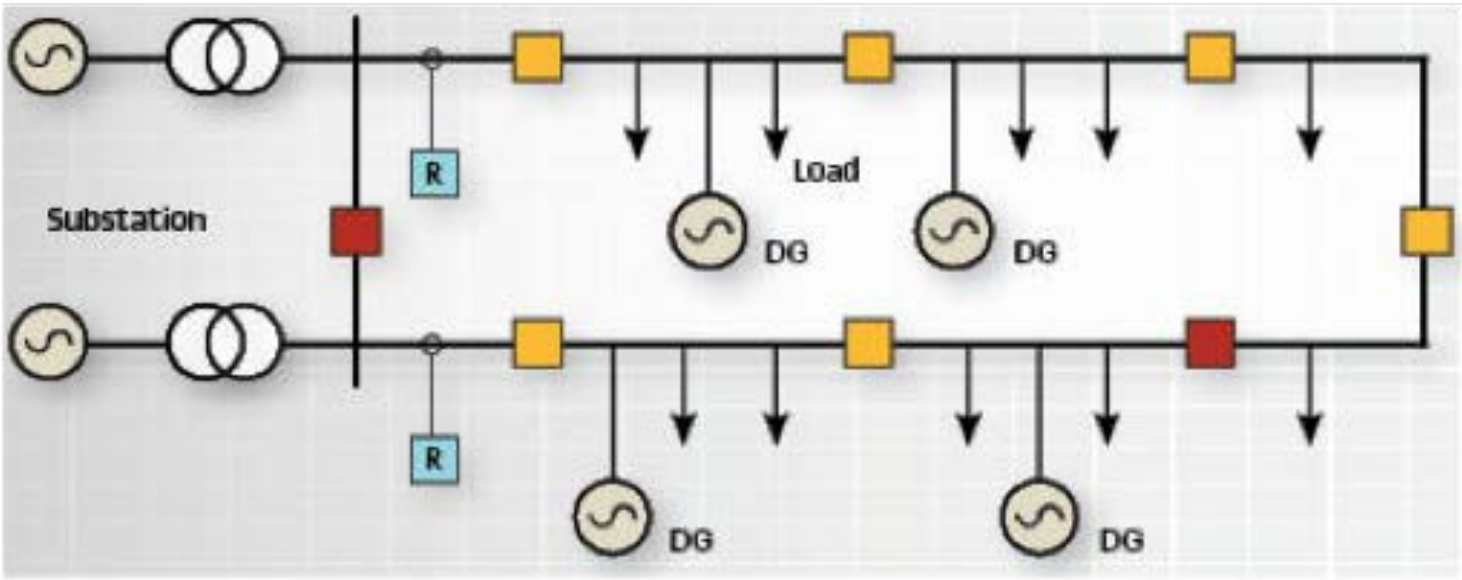
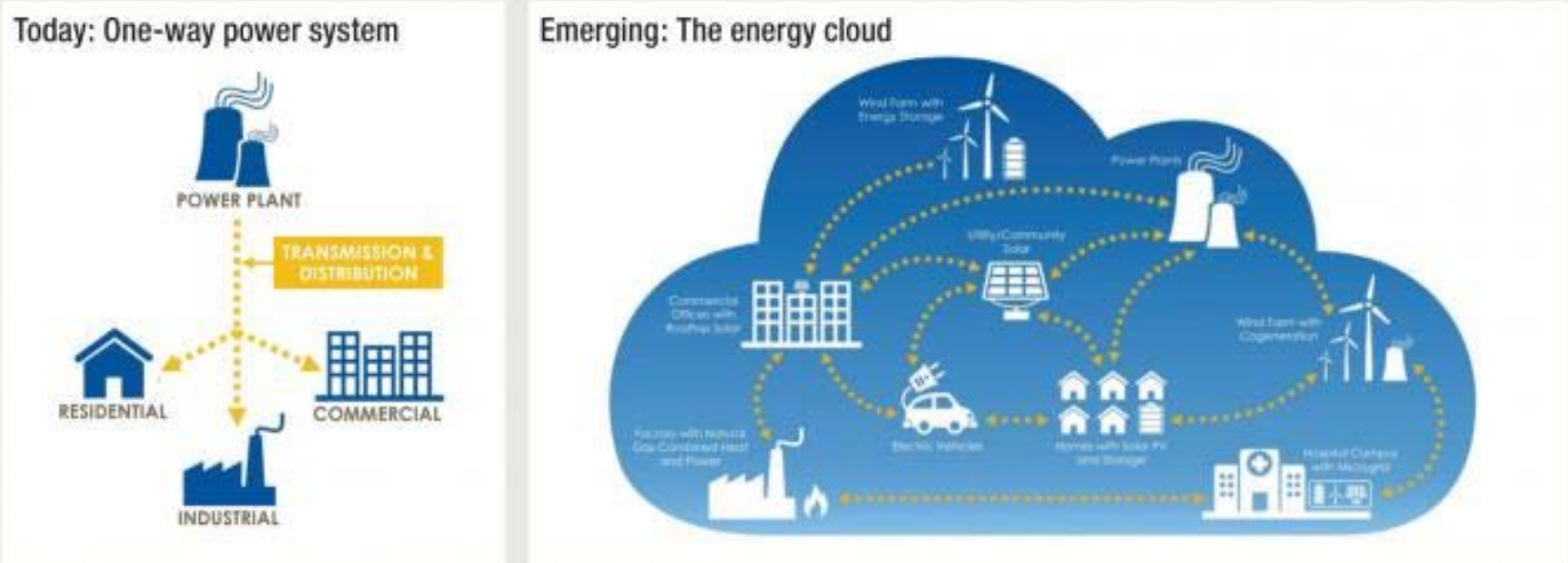


FIG. 1 **FROM GRID TO CLOUD**

Toward a network of networks.



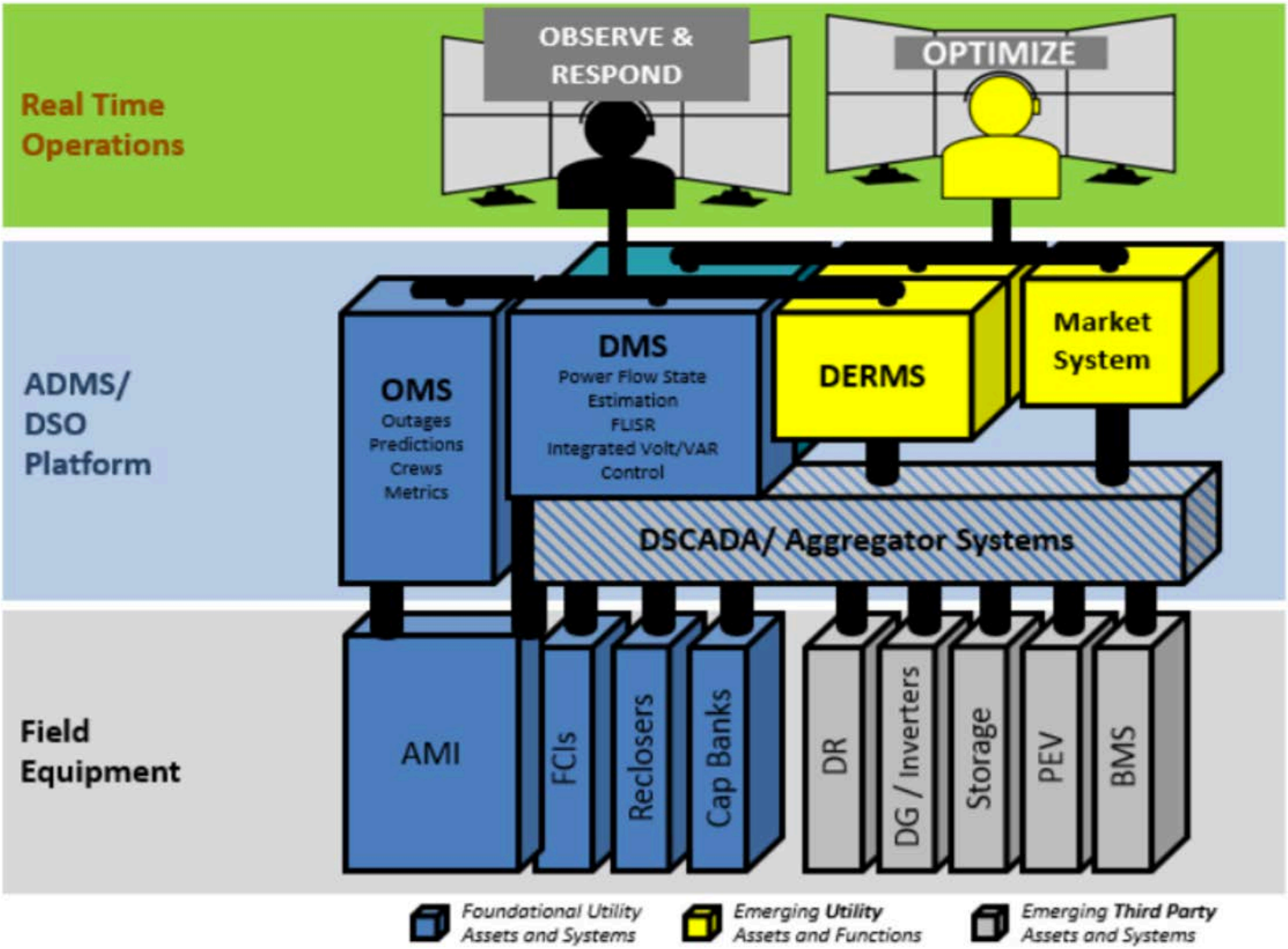
- Large, centrally located generation facilities
- Designed for one-way energy flow
- Utility controlled
- Technologically inflexible
- Simple market structures and transactions
- Highly regulated (rate base) and pass through

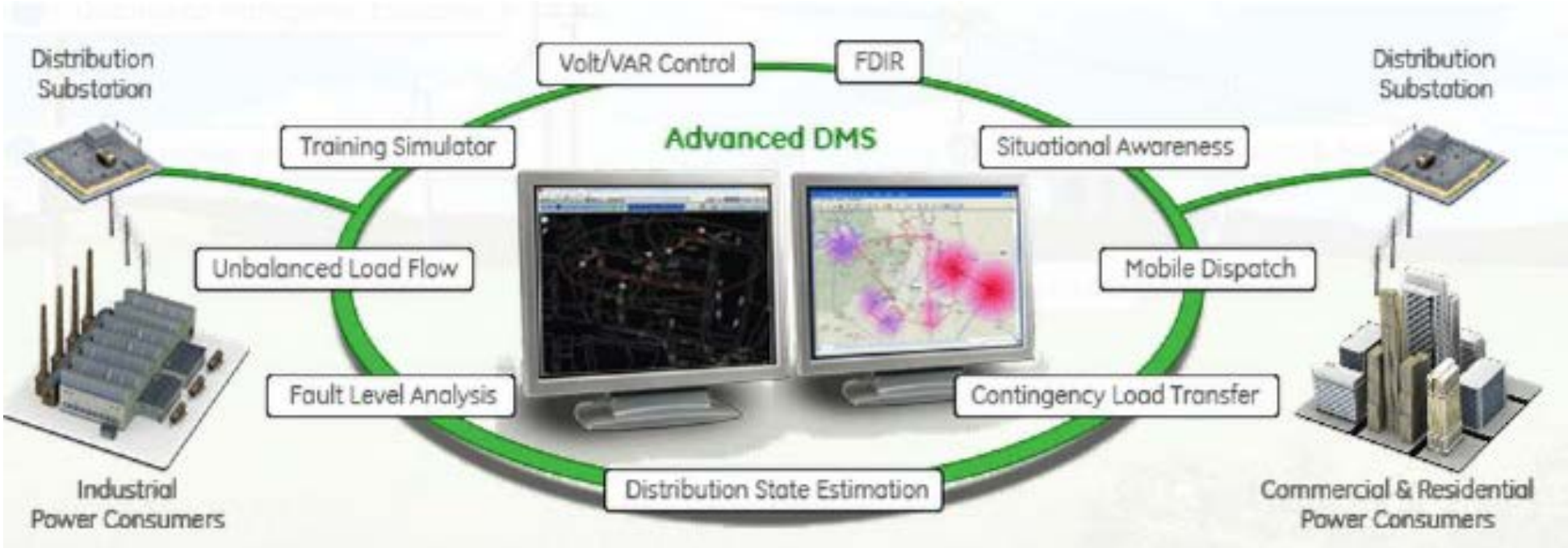
- Distributed energy resources
- Multiple inputs and users, supporting two-way energy flows
- Digitalization of the electric-mechanical infrastructure: smart grid and behind-the-meter energy management systems
- Flexible, dynamic, and resilient
- Complex market structures and transactions
- Regulation changing rapidly around renewables, distributed generation (solar, microgrids, storage), net metering, etc.

Emerging utility models

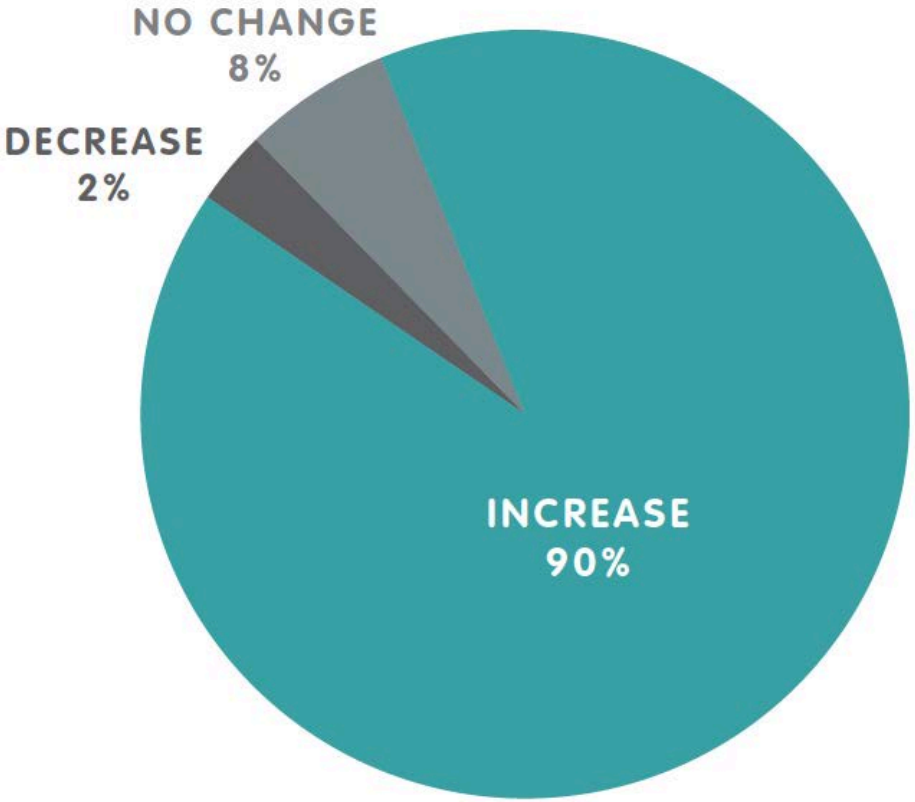
Utilities need to adopt a new structure to serve the customer

	From	To
Services & solutions	 • Static web/mobile experience • Electric service support, program enrollment	 • Structured platform enables trxs across traditional services and p2p scenarios • Dynamic/personalized customer experience
Transactive commodity exchange	 • Flat tariff structure based on rate class • No sensitivity to location or temporal value of service	 • Full real time exchanges (either bilateral or through a commodity exchange – e.g., D-LMP)
System operation and planning	 • Traditional planning to accommodate central station generation • Static long-term planning process	 • Real-time power quality assessment and reliability monitoring • Connected distributed architecture
System operation and planning	 • Traditional grid infrastructure • One-way power flows • AMI network	 • Mass market DER integration with traditional infra. • Two-way power flows • Fully transparent system

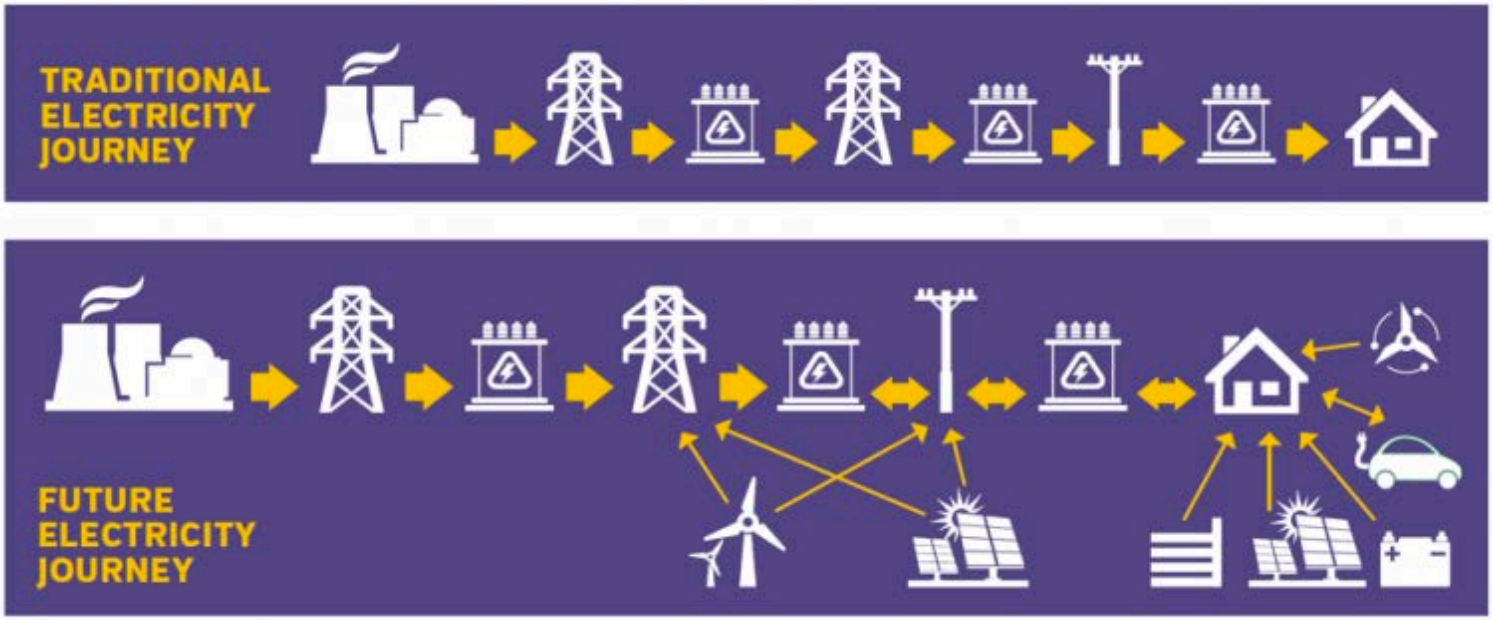

Real Time Operations
OBSERVE & RESPOND
OPTIMIZE
ADMS/ DSO Platform
OMS
Outages
Predictions
Crews
Metrics
DMS
Power Flow State Estimation
FLISR
Integrated Volt/VAR Control
DERMS
Market System
DSCADA/ Aggregator Systems
Field Equipment
AMI
FCIs
Reclosers
Cap Banks
DR
DG / Inverters
Storage
PEV
BMS
Foundational Utility Assets and Systems
Emerging Utility Assets and Functions
Emerging Third Party Assets and Systems

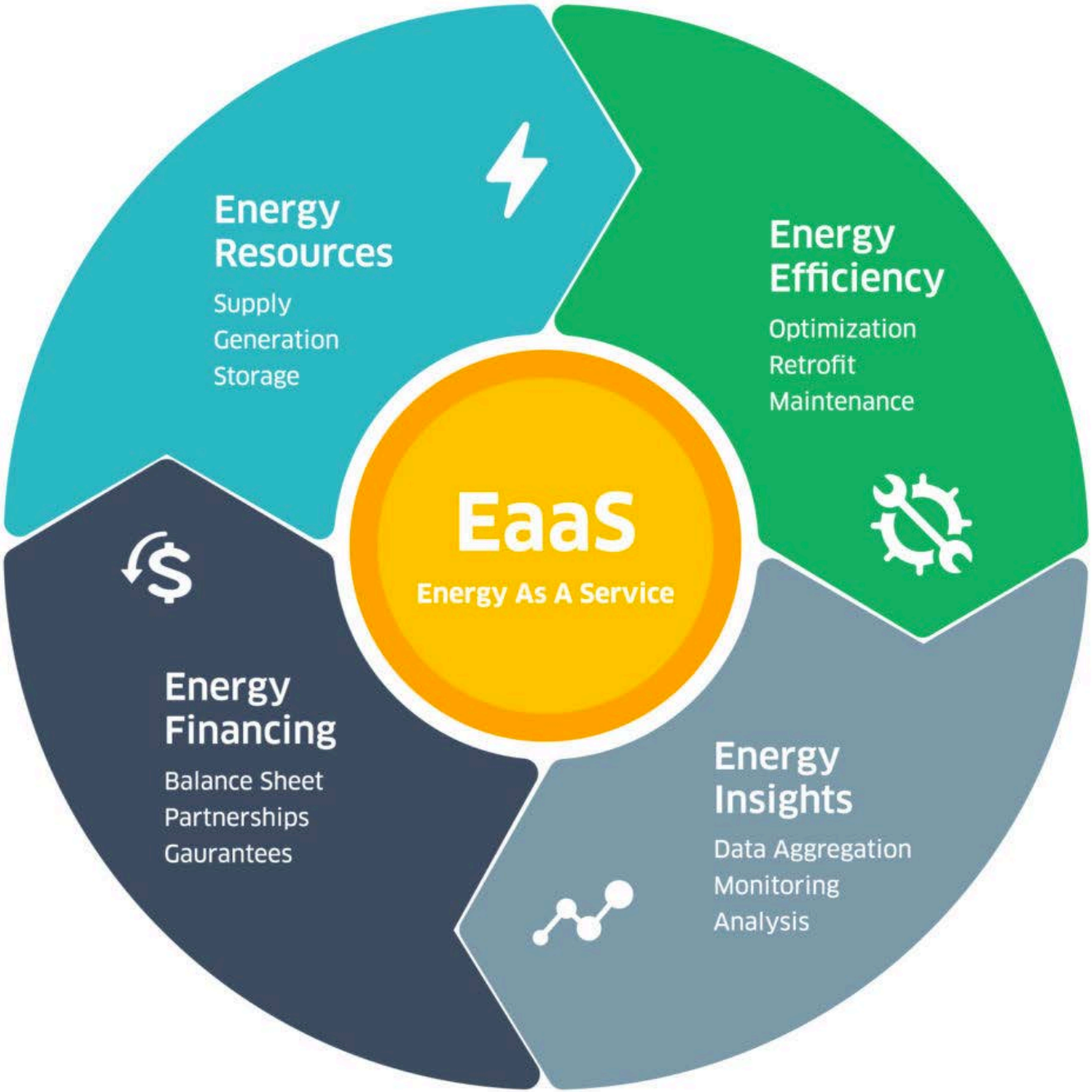

Distribution Substation
Volt/VAR Control
FDIR
Distribution Substation
Training Simulator
Advanced DMS
Situational Awareness
Unbalanced Load Flow
Mobile Dispatch
Fault Level Analysis
Contingency Load Transfer
Distribution State Estimation
Industrial Power Consumers
Commercial & Residential Power Consumers

CHANGE OF DA IMPORTANCE IN NEXT 3 TO 5 YEARS



Distribution System Operator




Energy Resources
Supply
Generation
Storage
Energy Efficiency
Optimization
Retrofit
Maintenance
EaaS
Energy As A Service
Energy Financing
Balance Sheet
Partnerships
Gaurantees
Energy Insights
Data Aggregation
Monitoring
Analysis

Transactive Energy Markets (Block Chain / Cryptocurrency)

NEW BUSINESS MODELS

LET GO OF COST-PLUS MONOPOLY MINDSET

COMPETE FOR CUSTOMERS

YOUR CUSTOMERS DID NOT SIGN
THE LONG-TERM, ALL-REQUIREMENTS
WHOLESALE POWER PURCHASE AGREEMENT!

Trying to ensure full cost recovery
with declining sales
is not a sustainable tactic
in a competitive market

Business viability depends upon
cutting costs
adding value
new revenue sources


It's Electric: Understanding
Beneficial Electrification