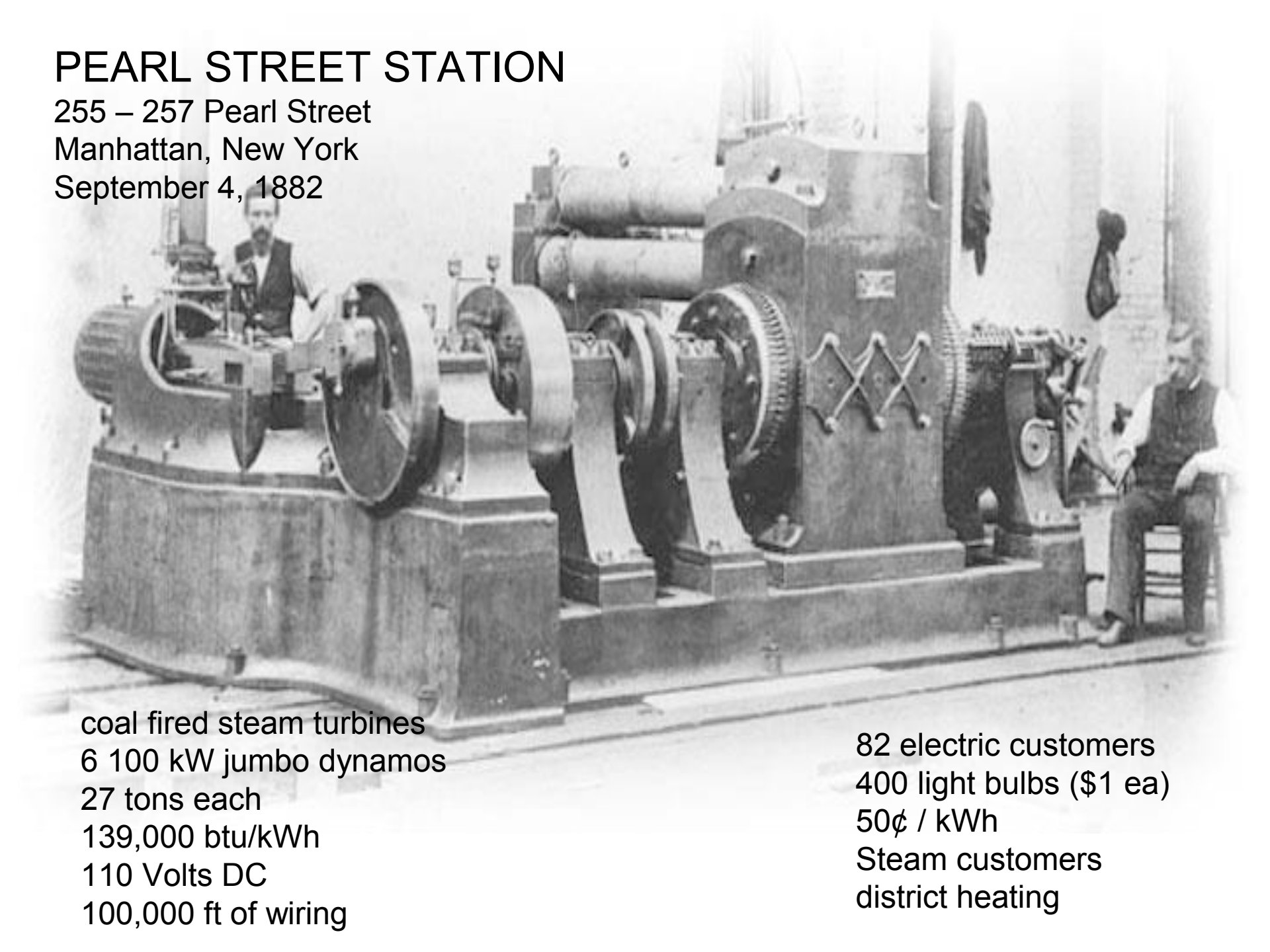
Revolutionary Change In The Electric Utility Industry

- Eroding Legacy Foundations
- Disruptive New Developments

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

AC/DC

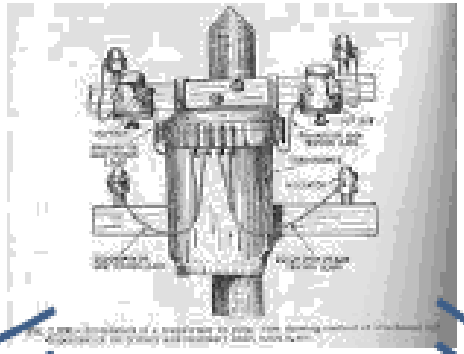
Nikola Tesla

Thomas Edison

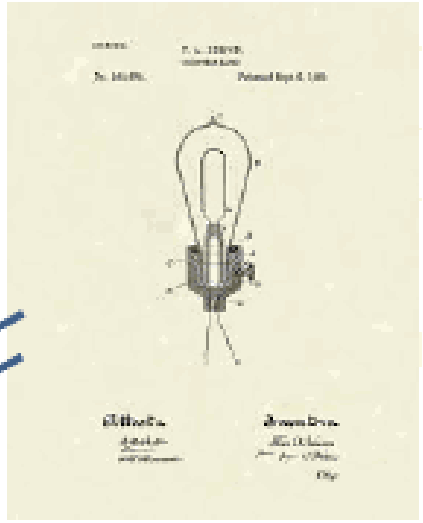
Niagara Falls power Co. 1895
The first major hydro-electric power plant in the world
Adams Station, power houses #1+ #2 and transformer building

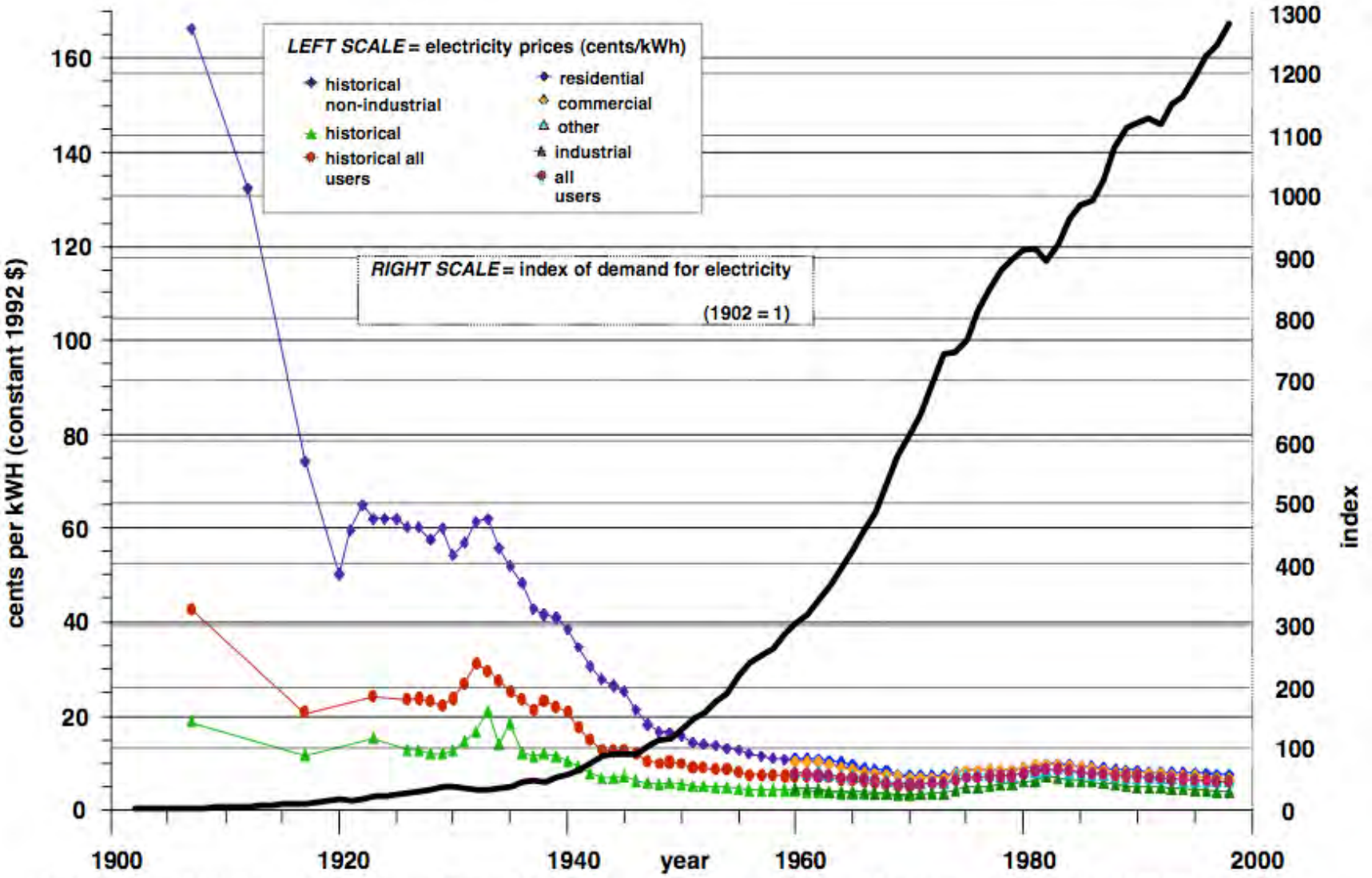
Pearl Street Station

electric pole

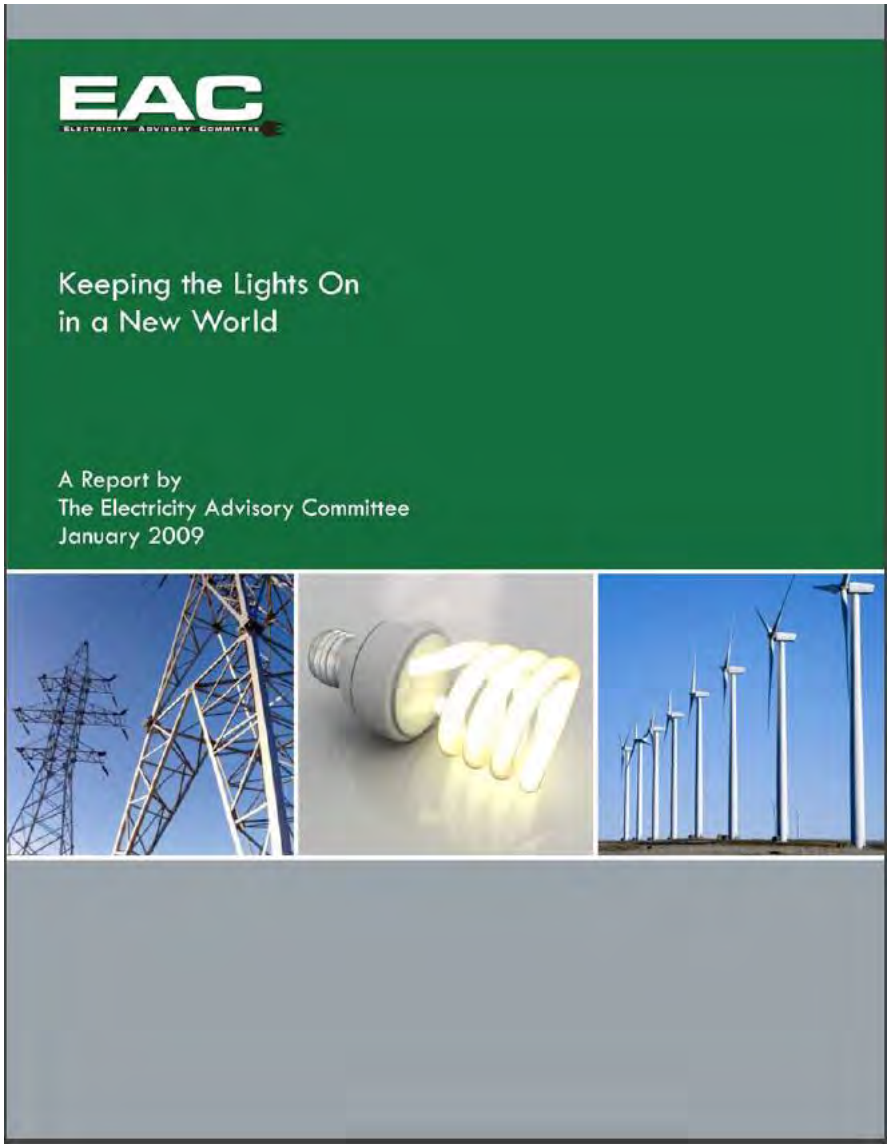


electric light



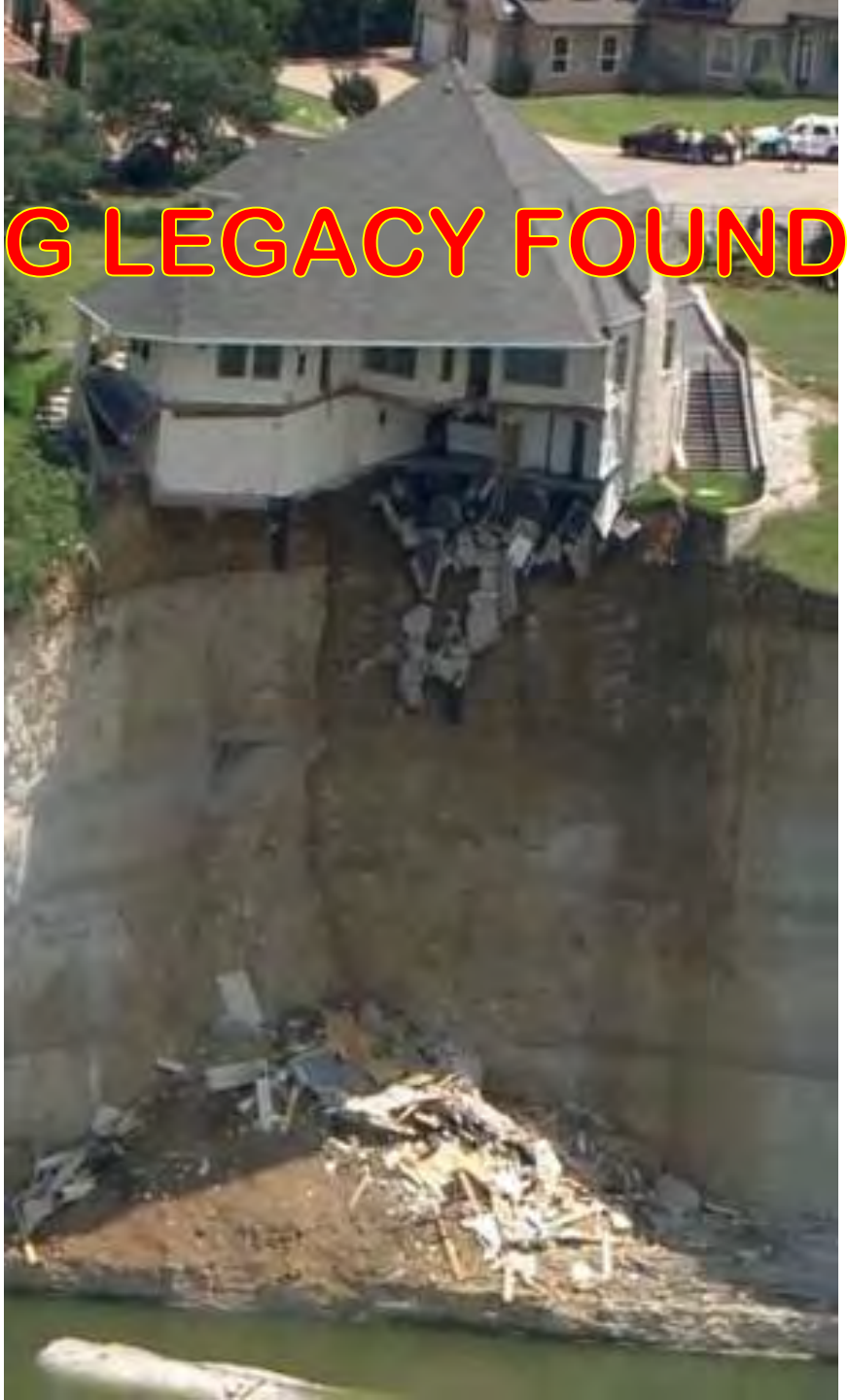


Data sources: 1960-1998: Annual Energy Review Table 8.13 *1907-1970: Historical Statistics: Vol 1, Series S116,118, 119*

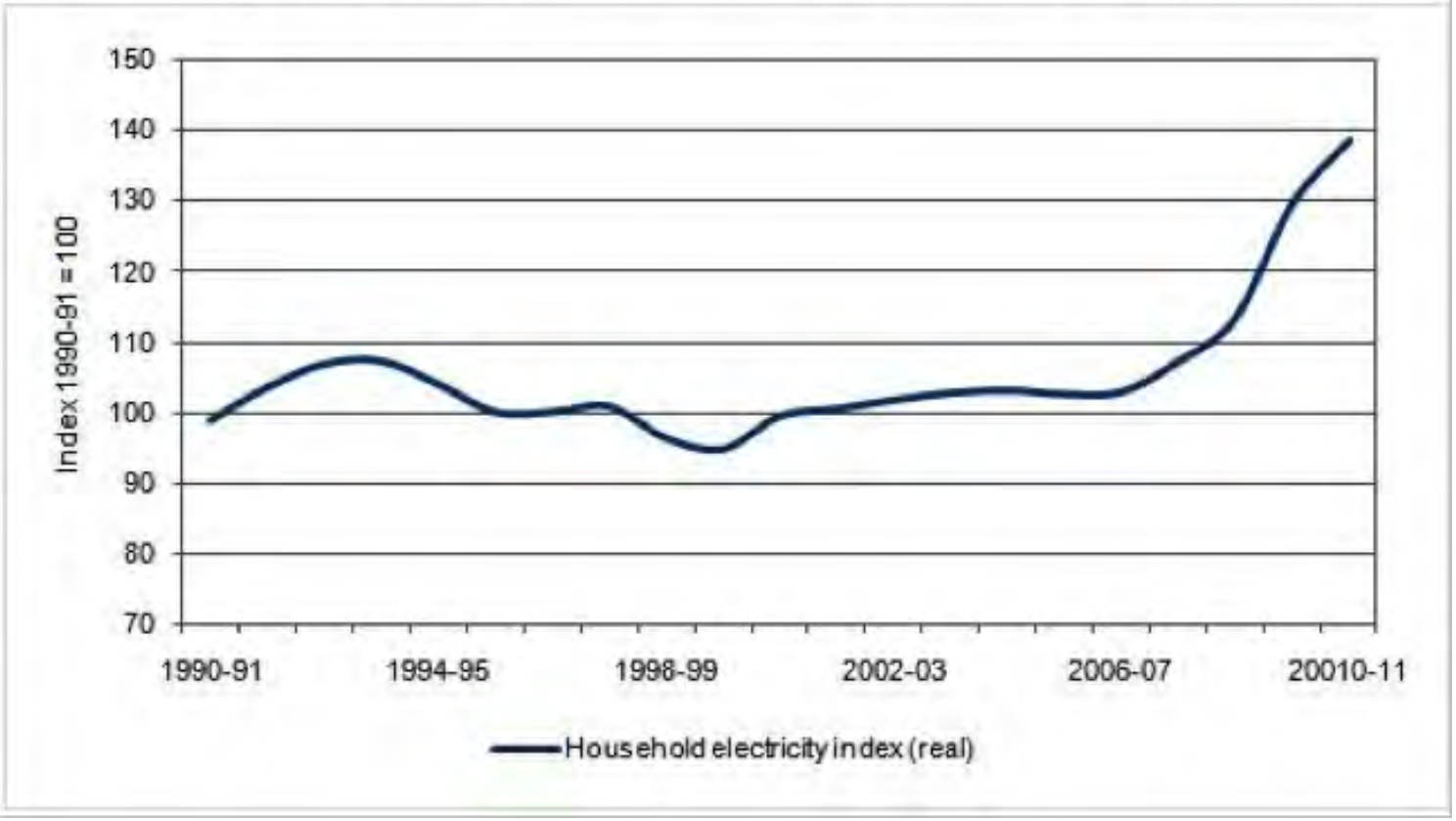


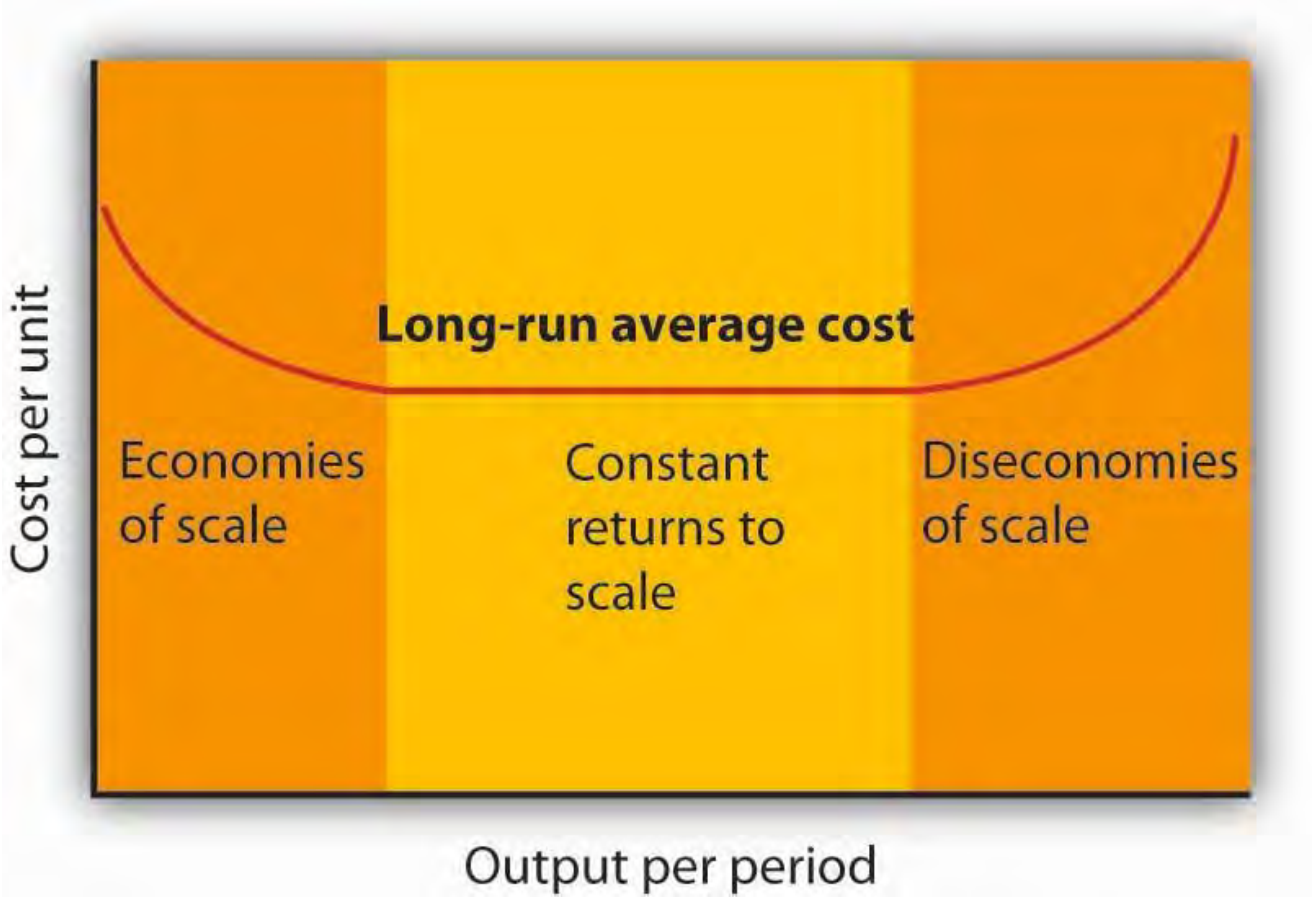
". . . the current electric power delivery system infrastructure . . . will be unable to ensure a reliable, cost-effective, secure, and environmentally sustainable supply of electricity for the next two decades . . . Much of the electricity supply and delivery infrastructure is nearing the end of its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

ERODING LEGACY FOUNDATIONS



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

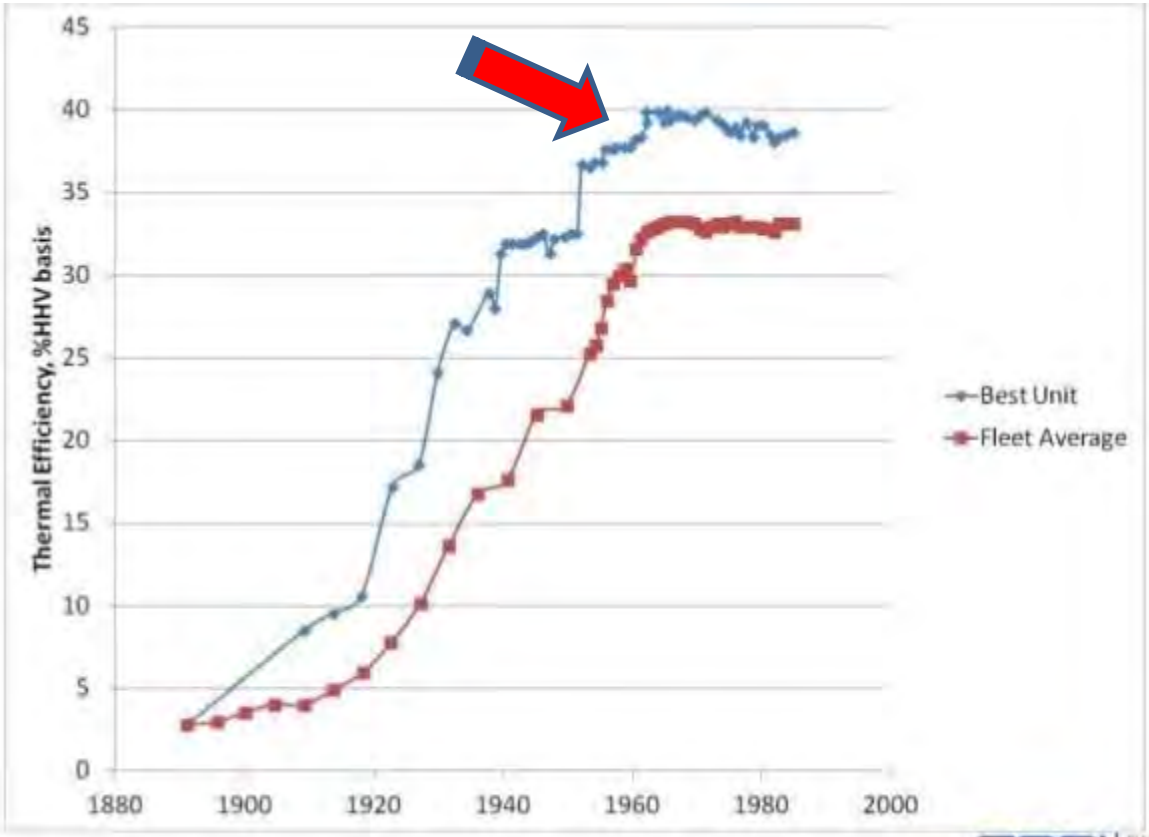


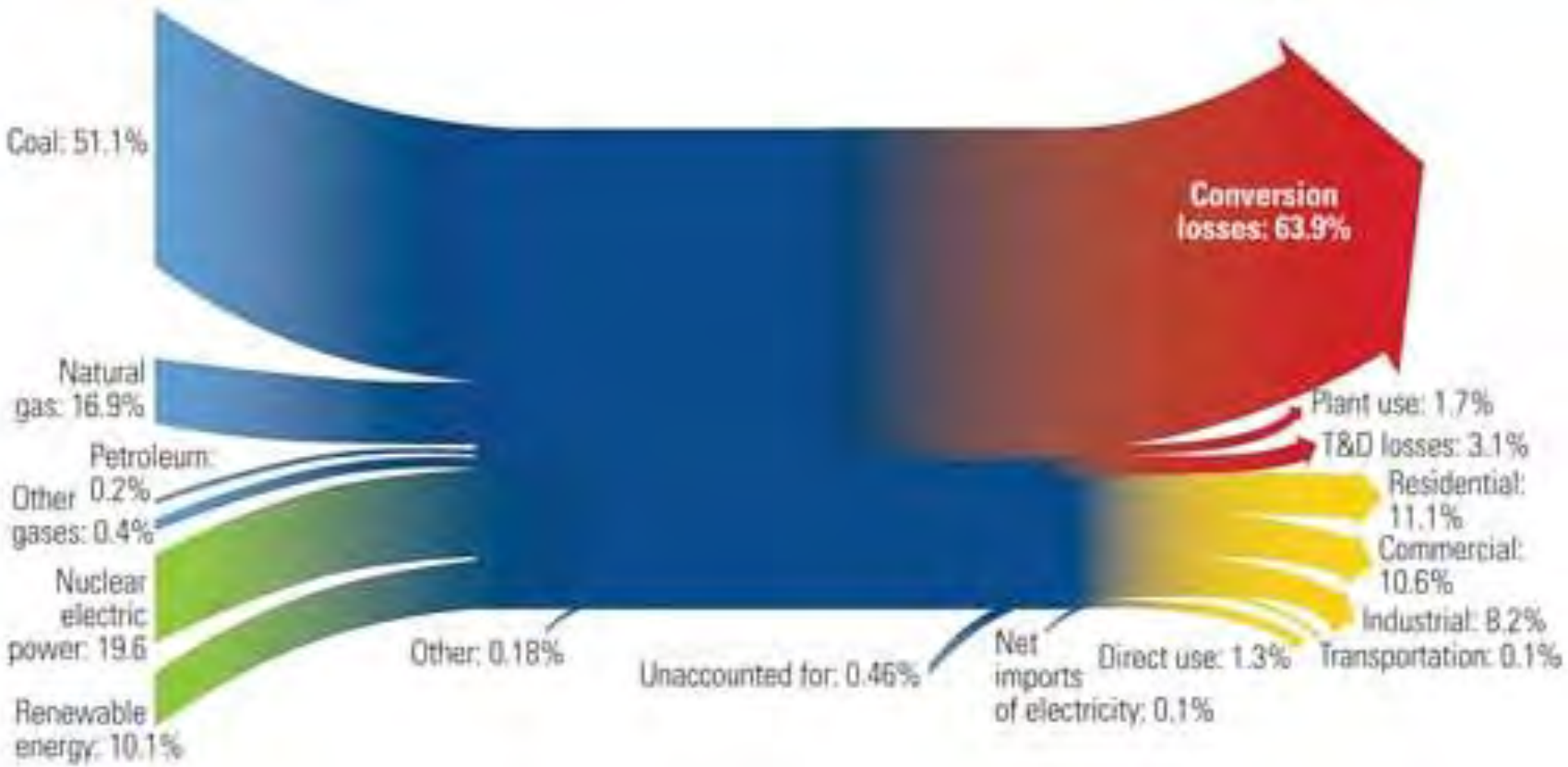

Cost per unit
Long-run average cost
Economies of scale
Constant returns to scale
Diseconomies of scale
Output per period

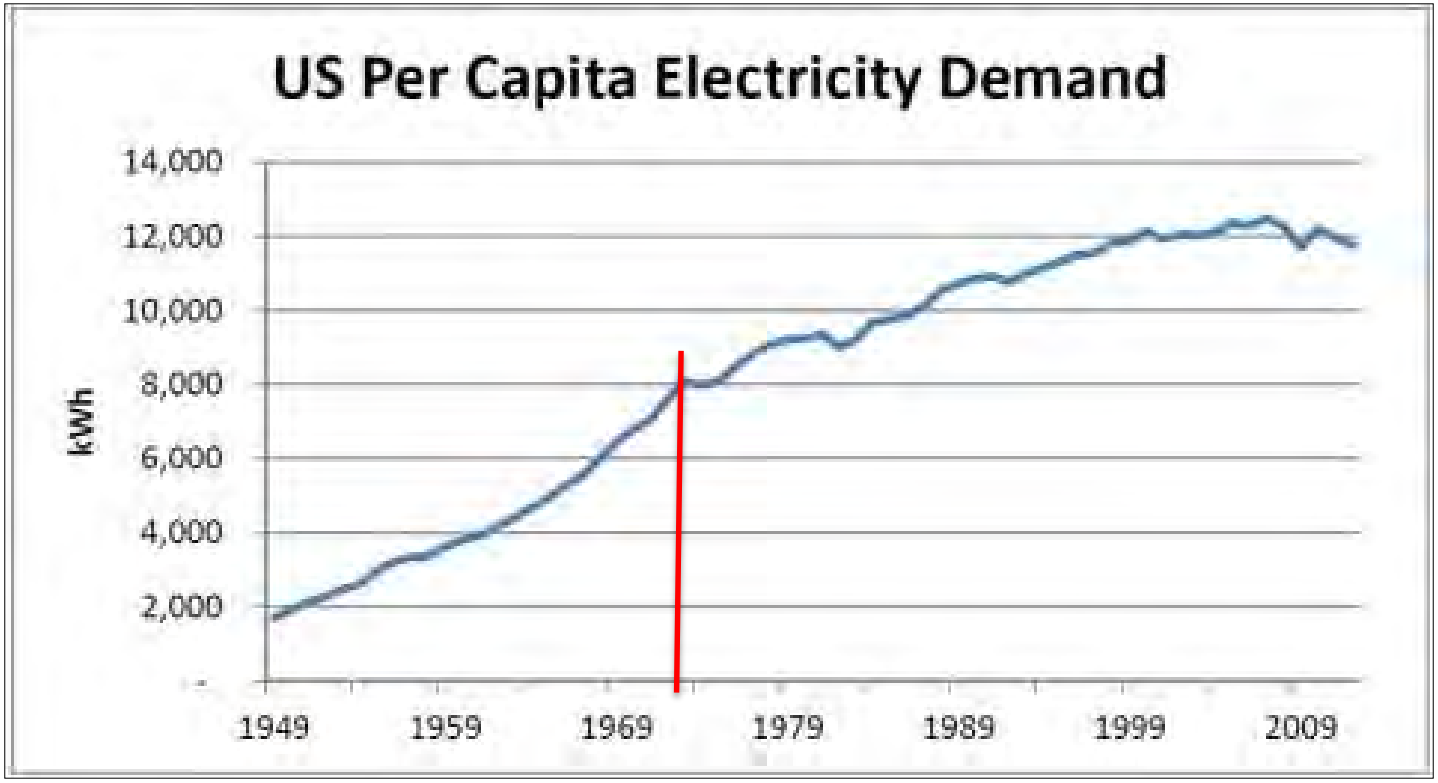

RISK

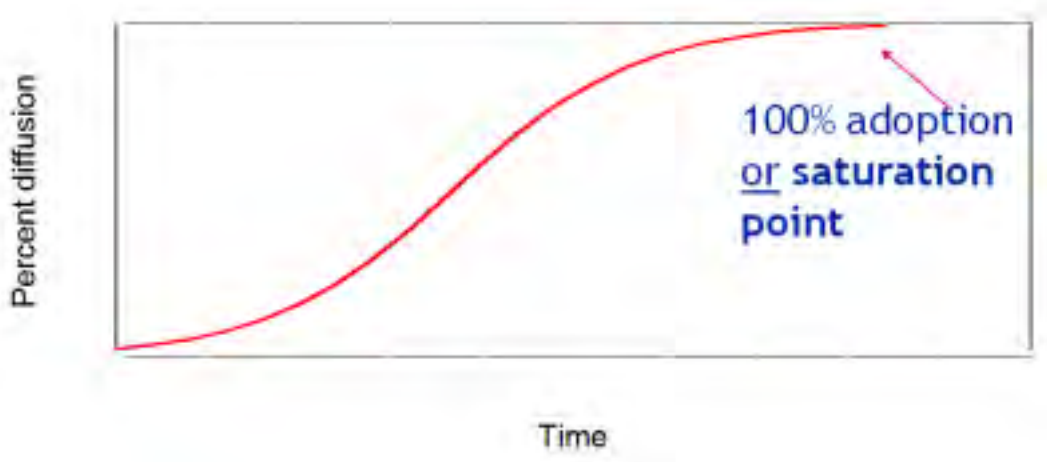
RISK

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




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%
Direct use: 1.3%
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%


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


Percent diffusion
100% adoption
or saturation
point
Time

ENERGY

EFFICIENCY & CONSERVATION

✓ Same output for lesser energy.

Efficiency

By buying efficient appliances.

✓ Reduce consumption or stop wastage to save energy.

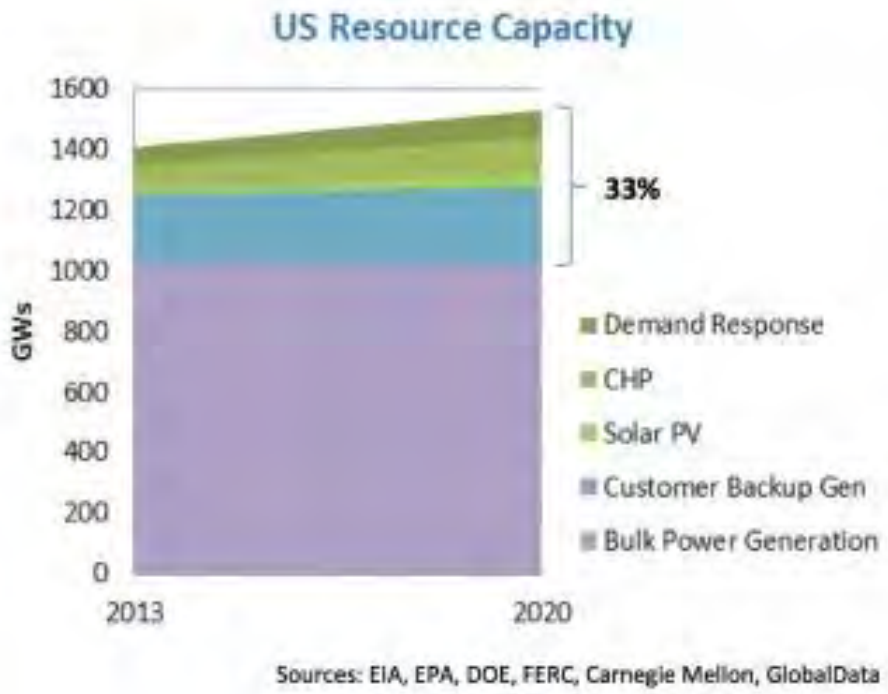
Conservation

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



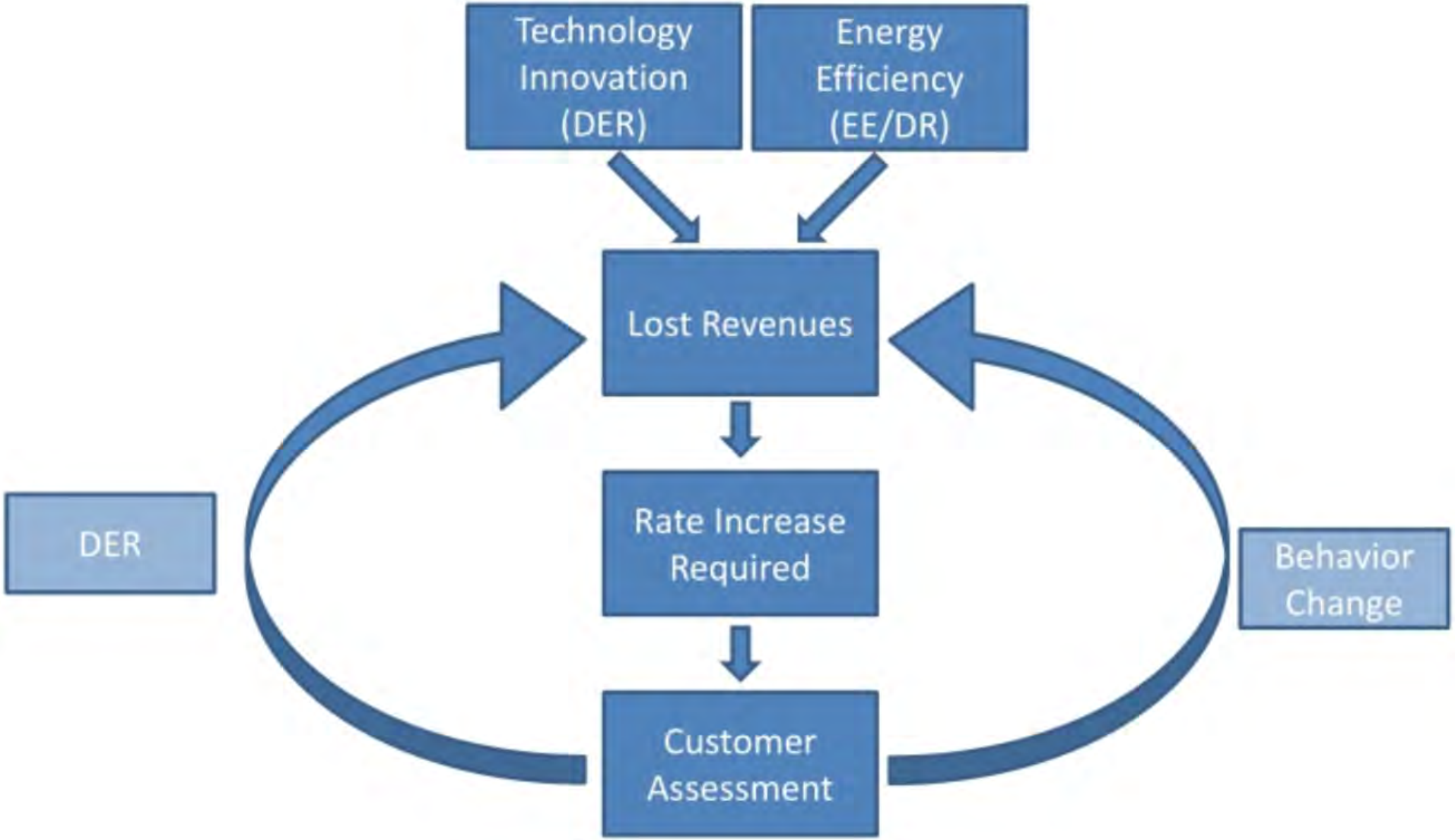
Sources: EIA, EPA, DOE, FERC, Carnegie Mellon, GlobalData

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***

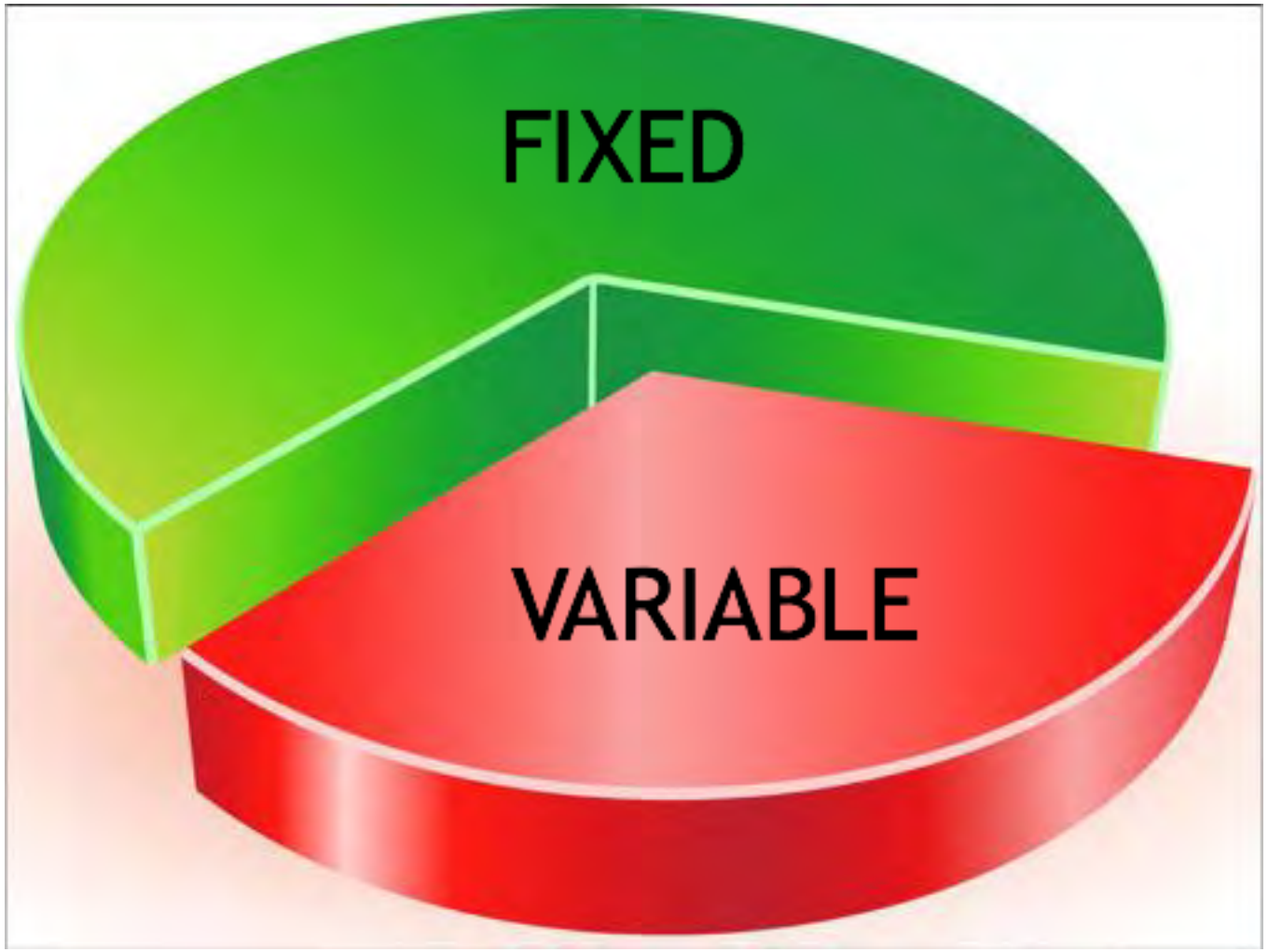

HC 161
CB
100
ONE HUNDRED DOLLAR


costs

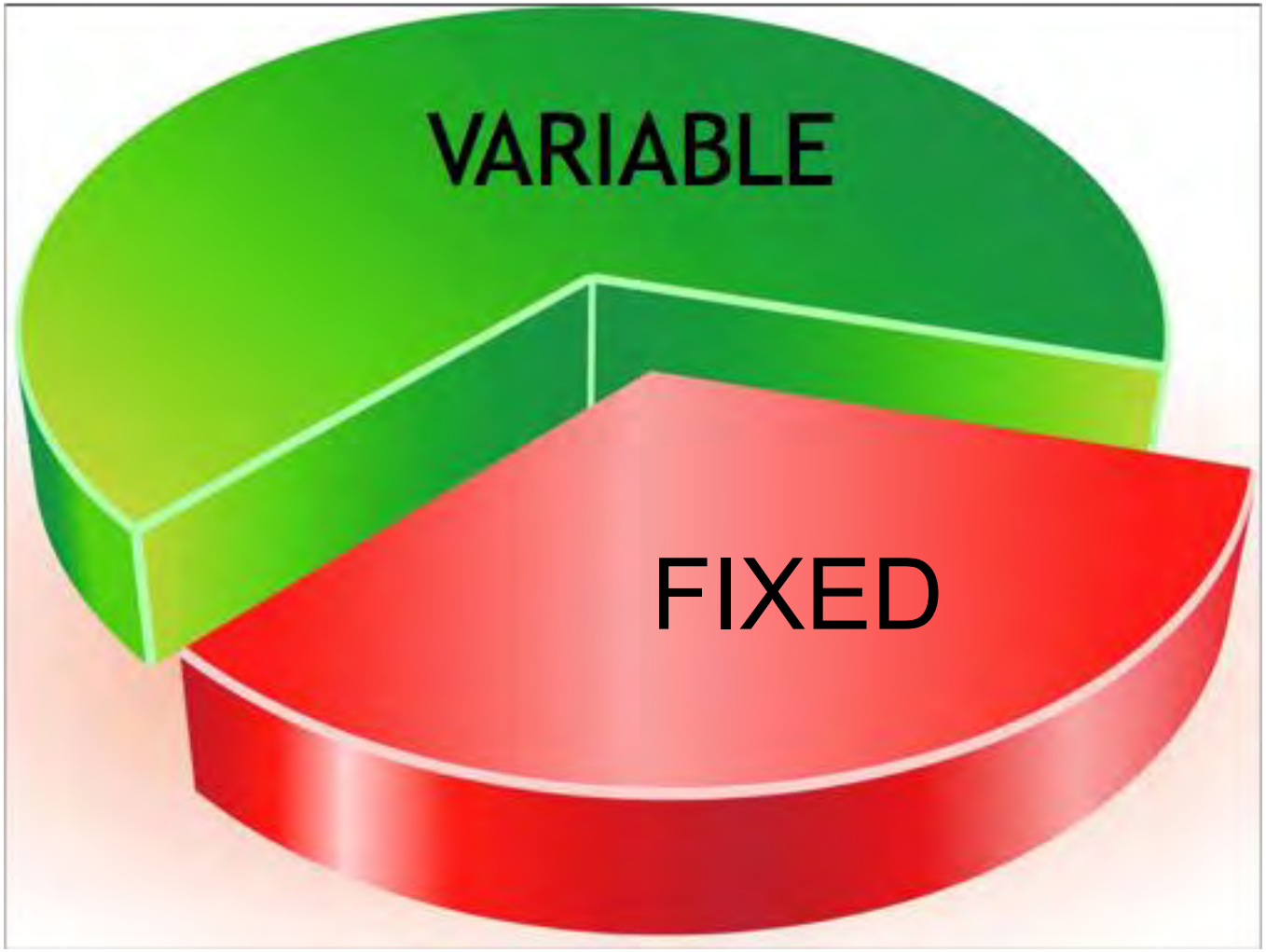
Vicious Cycle from Disruptive Forces



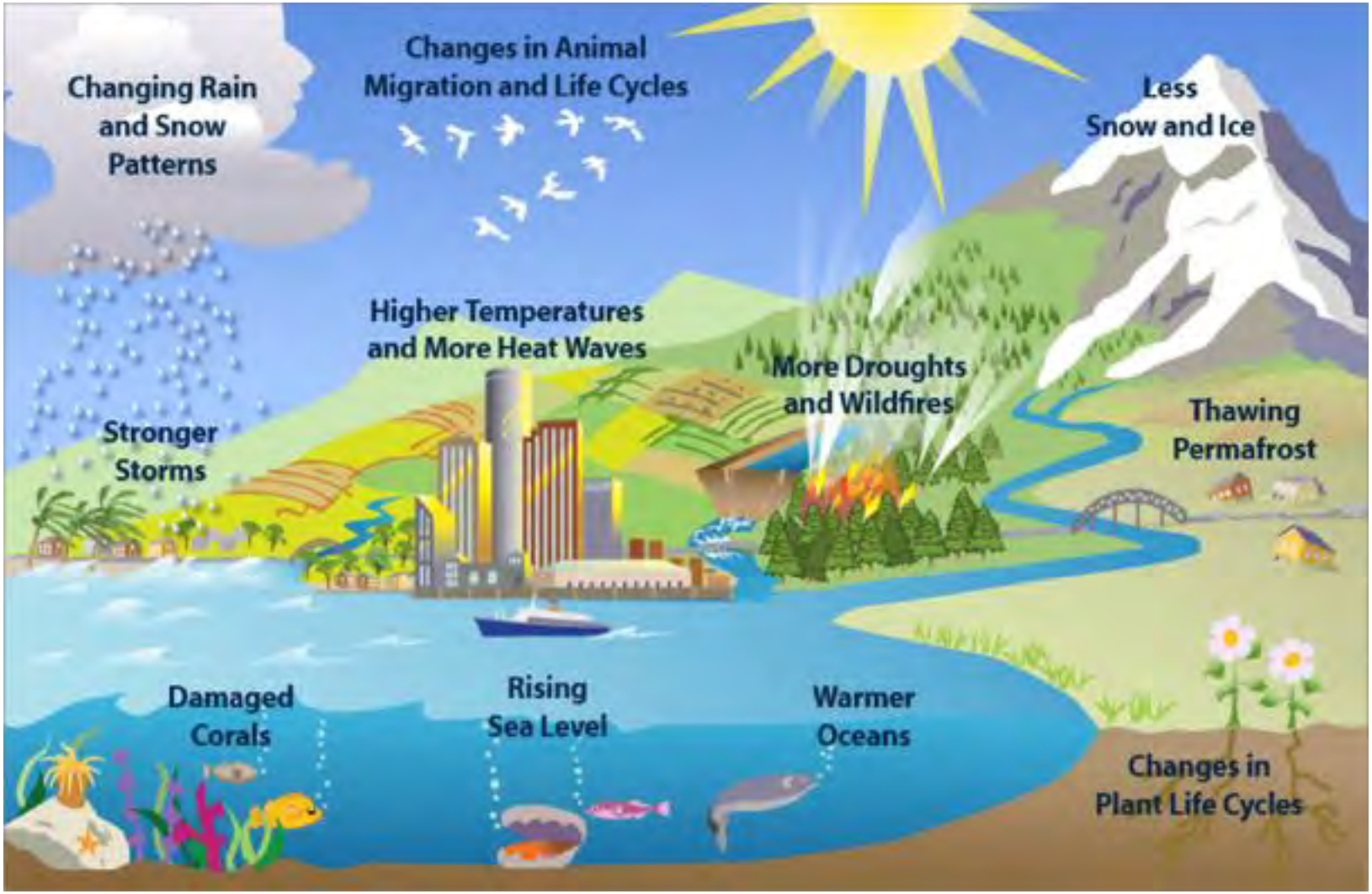
$$ COST $$



$$ REVENUE $$



Environmental Indifference


Changing Rain and Snow Patterns
Changes in Animal Migration and Life Cycles
Less Snow and Ice
Higher Temperatures and More Heat Waves
More Droughts and Wildfires
Thawing Permafrost
Stronger Storms
Damaged Corals
Rising Sea Level
Warmer Oceans
Changes in Plant Life Cycles

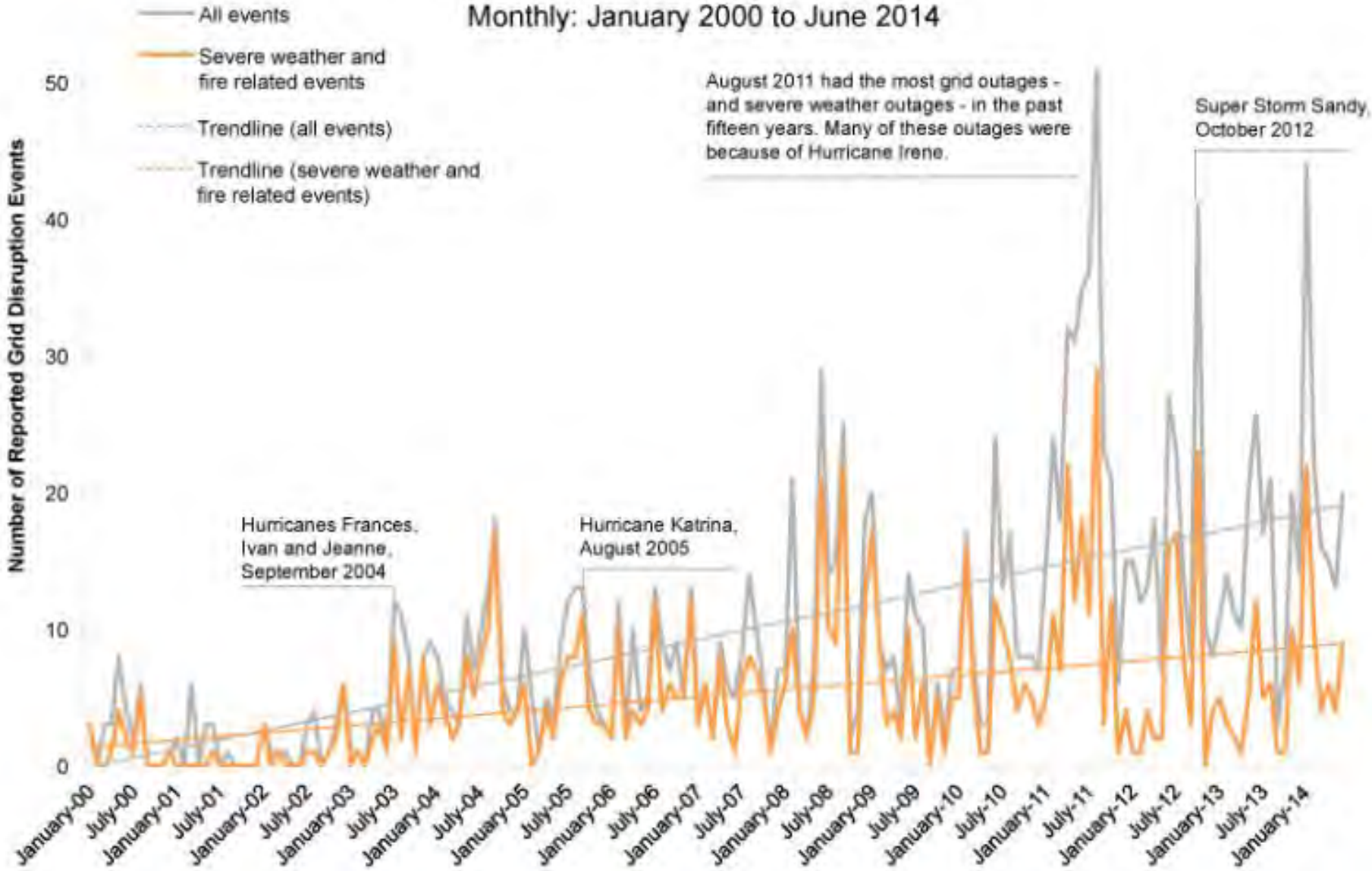
DEPRECIATION

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.

U.S. Electric Grid Disruptions

Monthly: January 2000 to June 2014



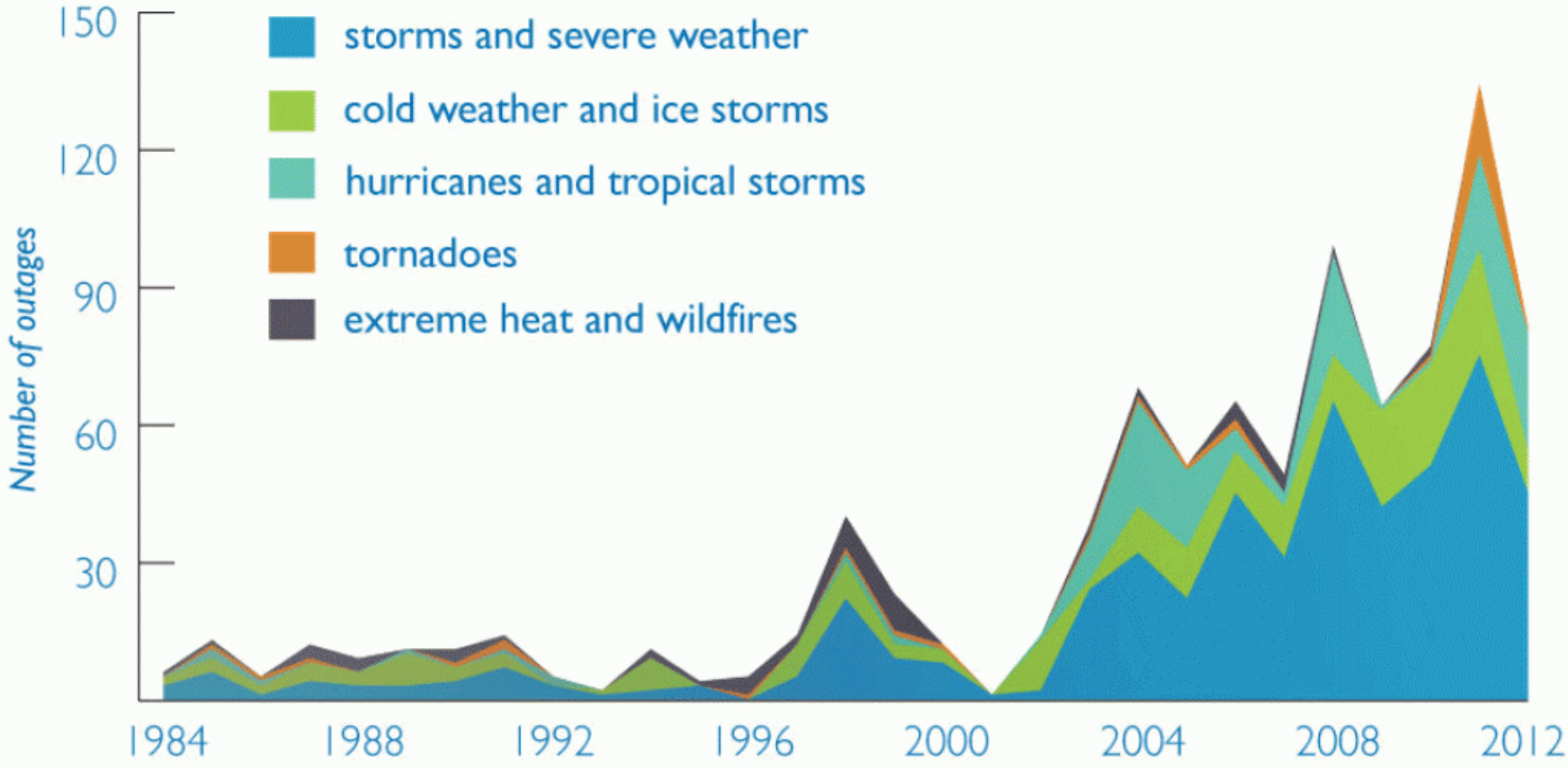
Electric grid disruption data, while far from perfect, shows that events - including severe weather events - have been on the rise over the past 15 years. There have been 1,652 reported grid outages since 2000, and 130 of them were in the past six months.

Data Source: Department of Energy/Energy Information Administration Form OE-471 annual summaries, https://www.oe.netl.doe.gov/OE417_annual_summary.aspx

JORDAN WIRFS-BROCK / INSIDE ENERGY

Extreme Weather Is Causing More Major Power Outages

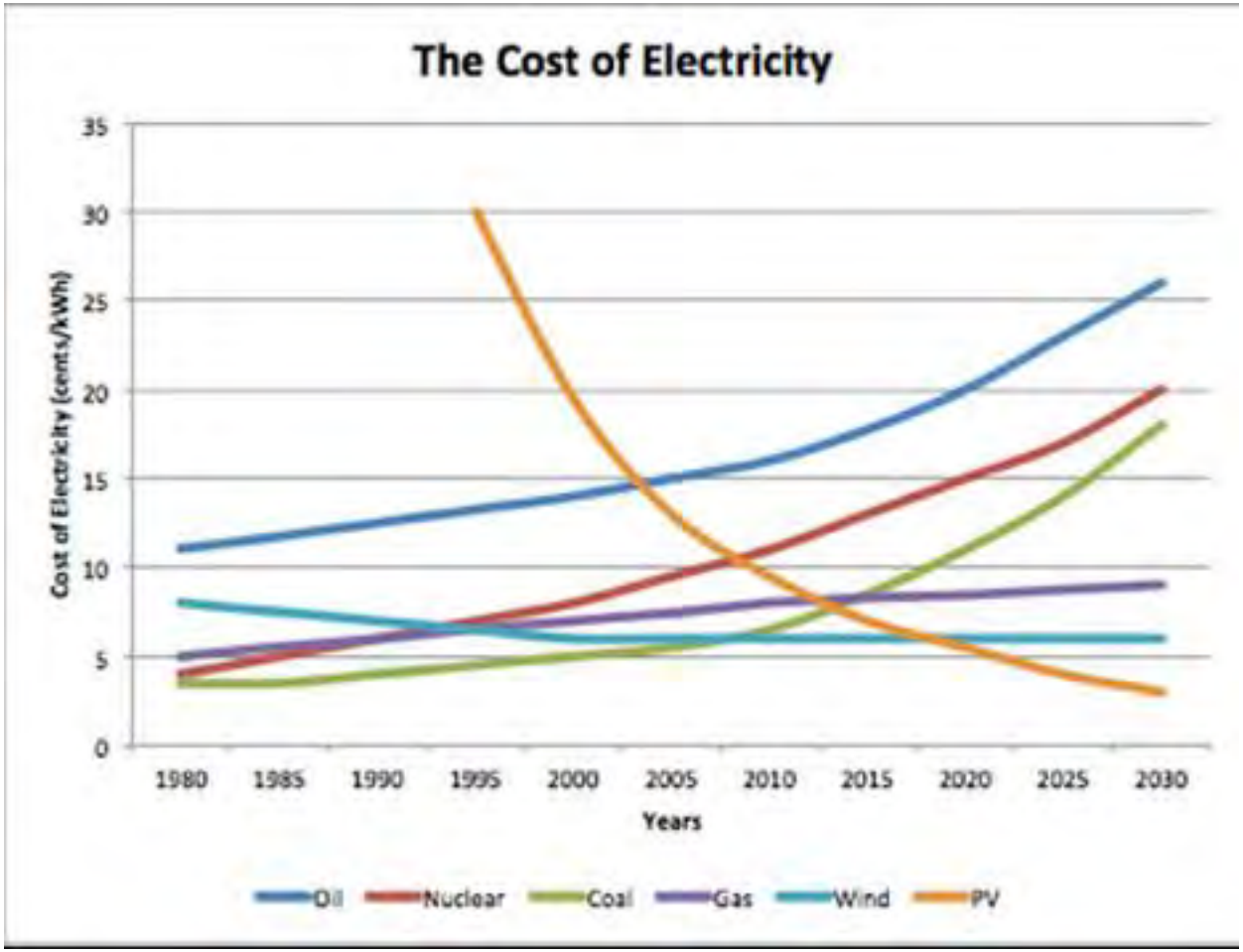
(major = at least 50,000 customers affected)



CLIMATE CENTRAL

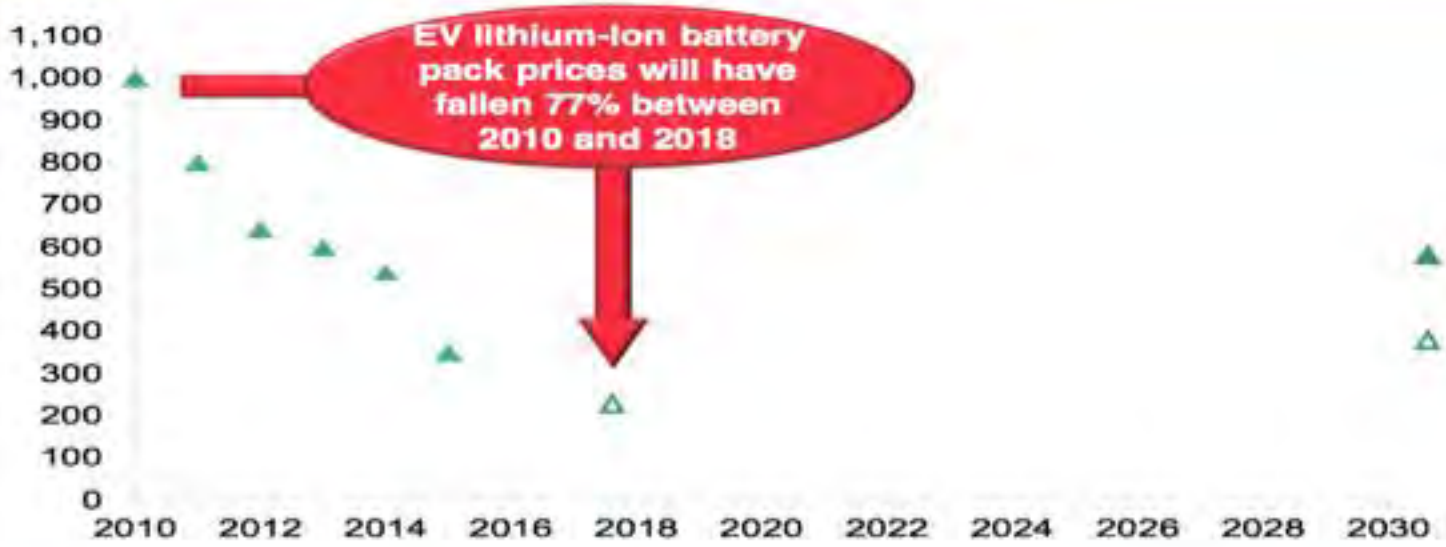

ENABLING
DISRUPTIVE
NEW TECHNOLOGIES

NEW ENERGY TECHNOLOGIES


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

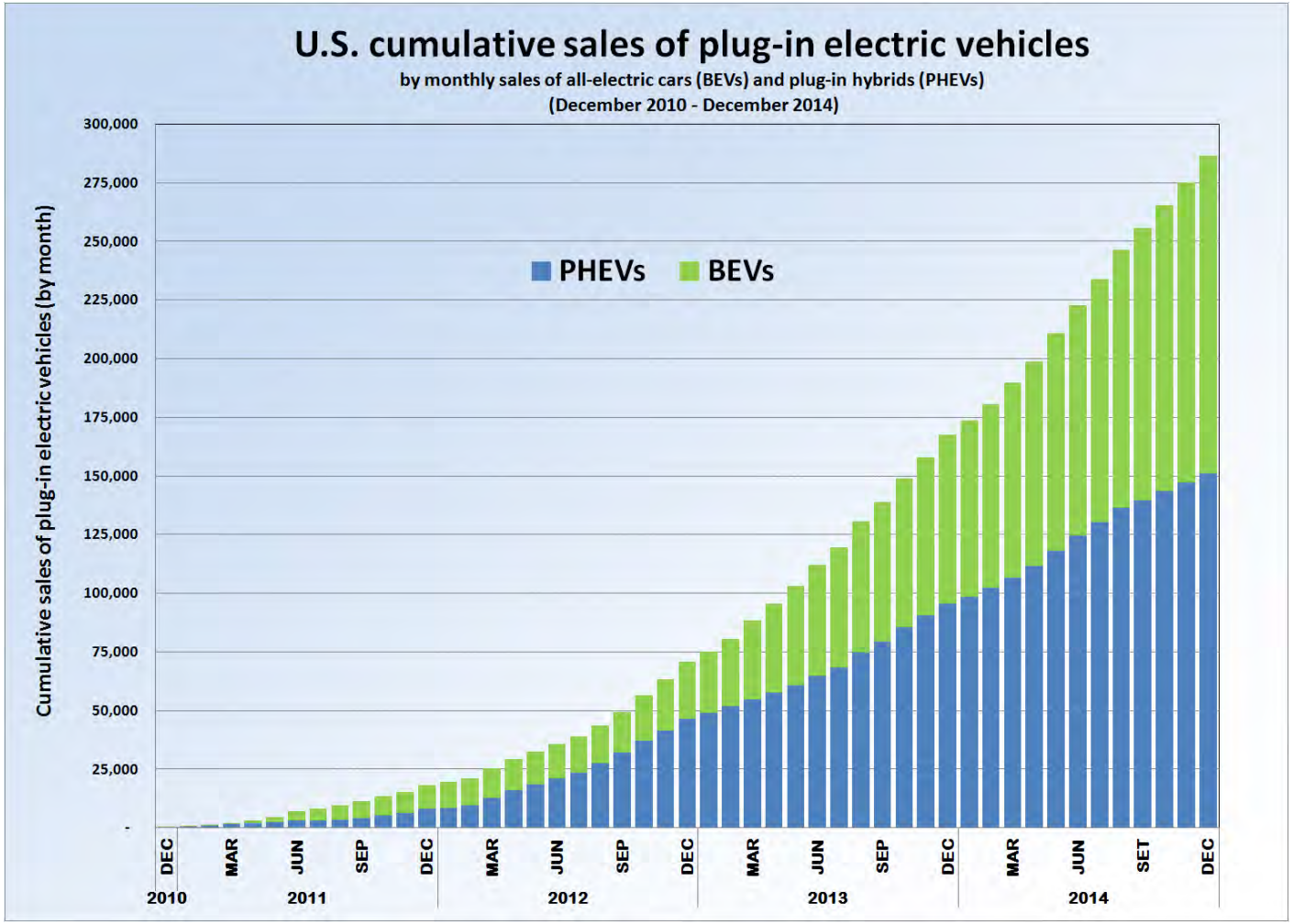
EV LITHIUM-ION BATTERY PACK PRICE
($/KWh)

Bloomberg
NEW ENERGY FINANCE



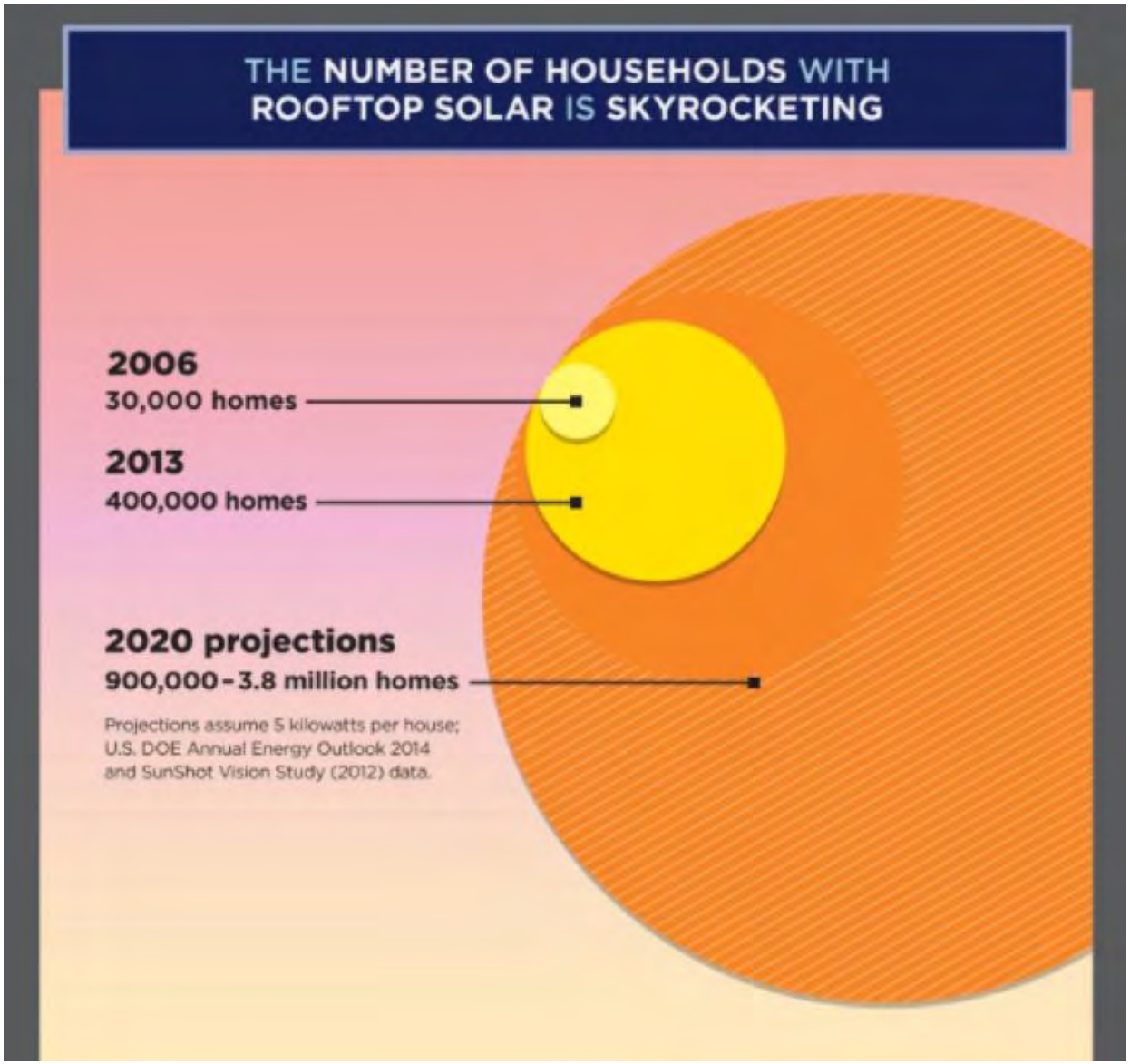
Note: Forecast range based on a learning rate of 14-20%. EV cost parity is calculated on an unsubsidised total cost of ownership (TCO) base. Date range reflects cross over with different vehicle classes in the US.

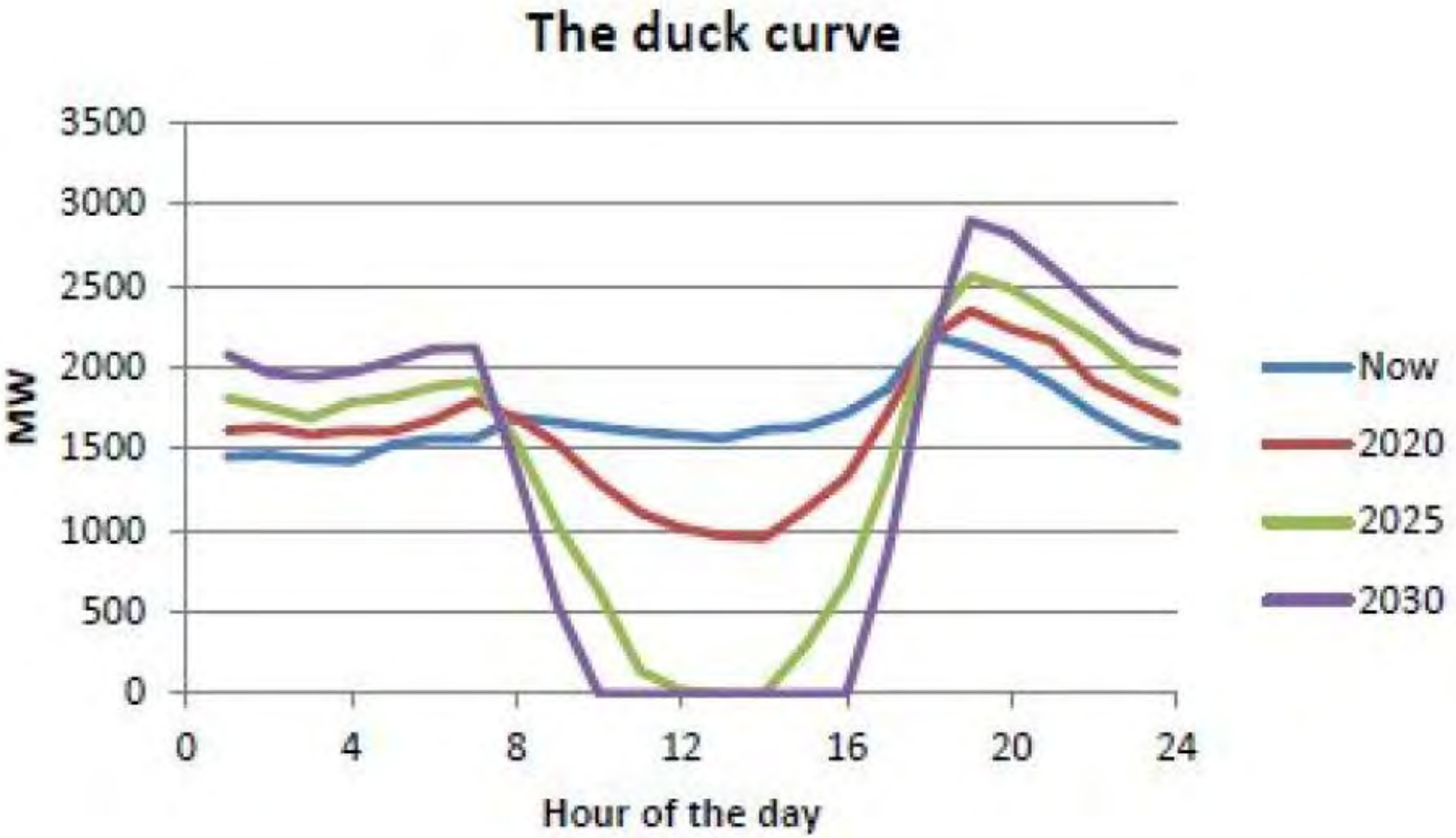
Source: Bloomberg New Energy Finance, EV lithium-ion battery price index


U.S. cumulative sales of plug-in electric vehicles
by monthly sales of all-electric cars (BEVs) and plug-in hybrids (PHEVs)
(December 2010 - December 2014)
Cumulative sales of plug-in electric vehicles (by month)
300,000
275,000
250,000
225,000
200,000
175,000
150,000
125,000
100,000
75,000
50,000
25,000
-
PHEVs
BEVs
DEC
MAR
JUN
SEP
DEC
MAR
JUN
SEP
DEC
MAR
JUN
SEP
DEC
MAR
JUN
SET
DEC
2010
2011
2012
2013
2014

Michael Liebreich
State of the Industry Keynote
BNEF Global Summit 2017

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


THE NUMBER OF HOUSEHOLDS WITH
ROOFTOP SOLAR IS SKYROCKETING
2006
30,000 homes
2013
400,000 homes
2020 projections
900,000 - 3.8 million homes
Projections assume 5 kilowatts per house;
U.S. DOE Annual Energy Outlook 2014
and SunShot Vision Study (2012) data.


The duck curve
3500
3000
2500
2000
1500
1000
500
0
MW
0
4
8
12
16
20
24
Hour of the day
Now
2020
2025
2030


GRID2DGE

Grid Energy Storage

Distributed Generation

Switches &
Power Electronics

Distributed Generation

Monitoring,
Communications
& Control (MC^2)

Energy Storage

Biopower Generation

Microturbine

Distributed Generation

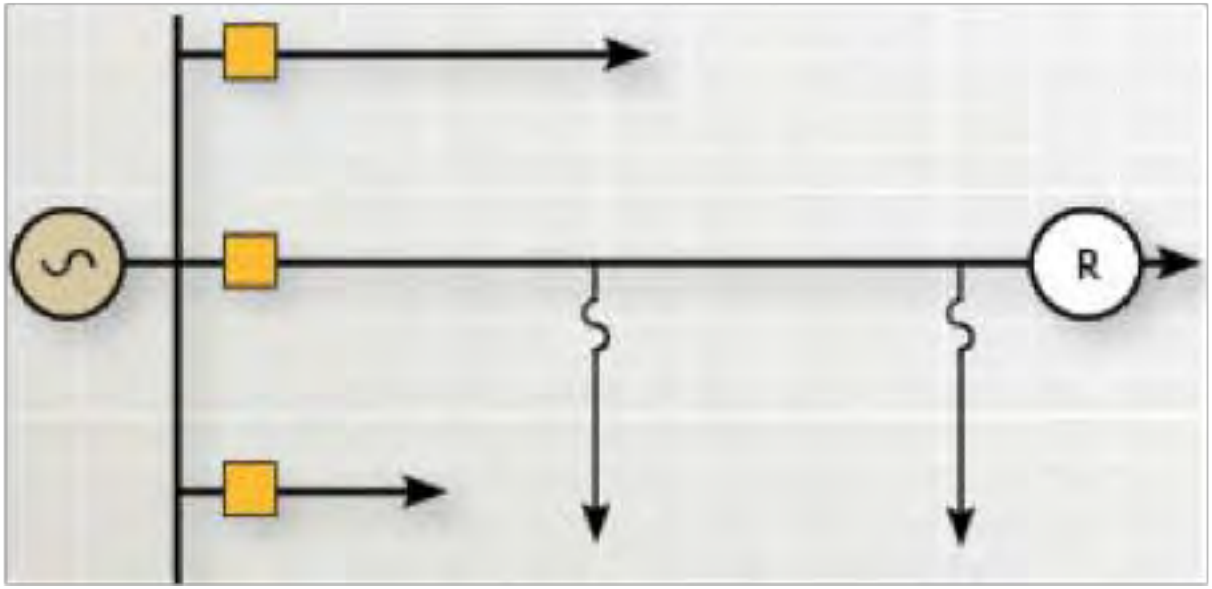
Electric Vehicles (EV)

Home Energy System

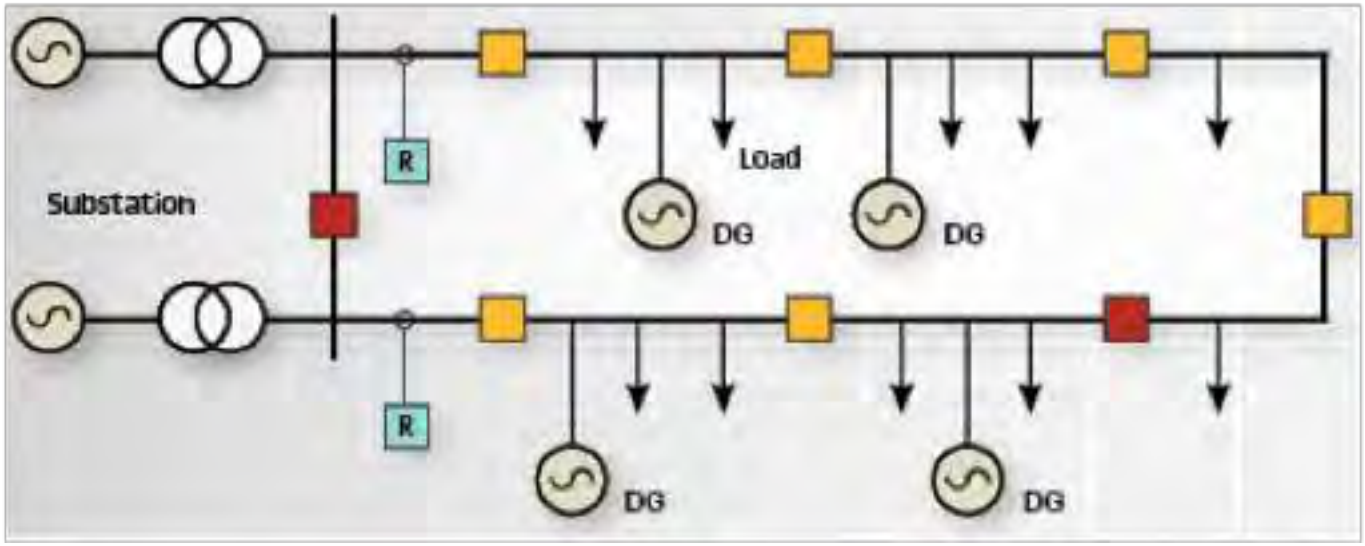
Fuel Cells

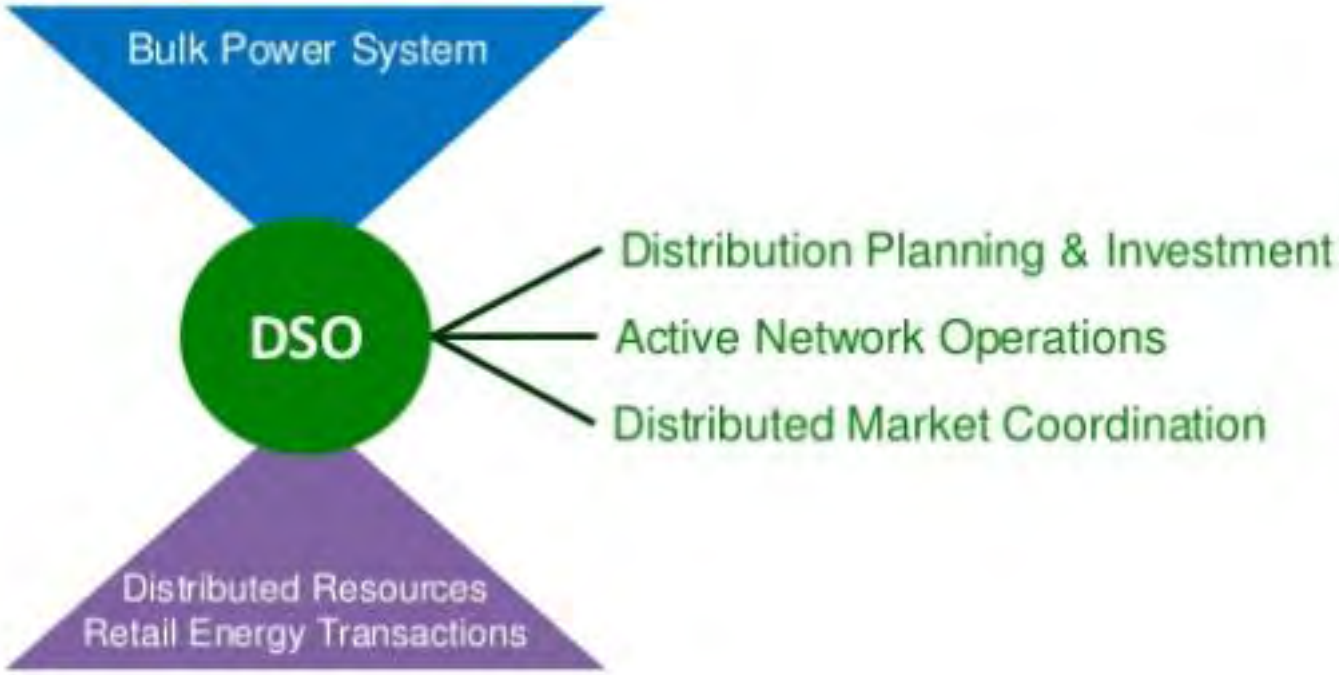
Distributed Generation

LEGACY DISTRIBUTION SYSTEM MODEL



DER DISTRIBUTION SYSTEM MODEL

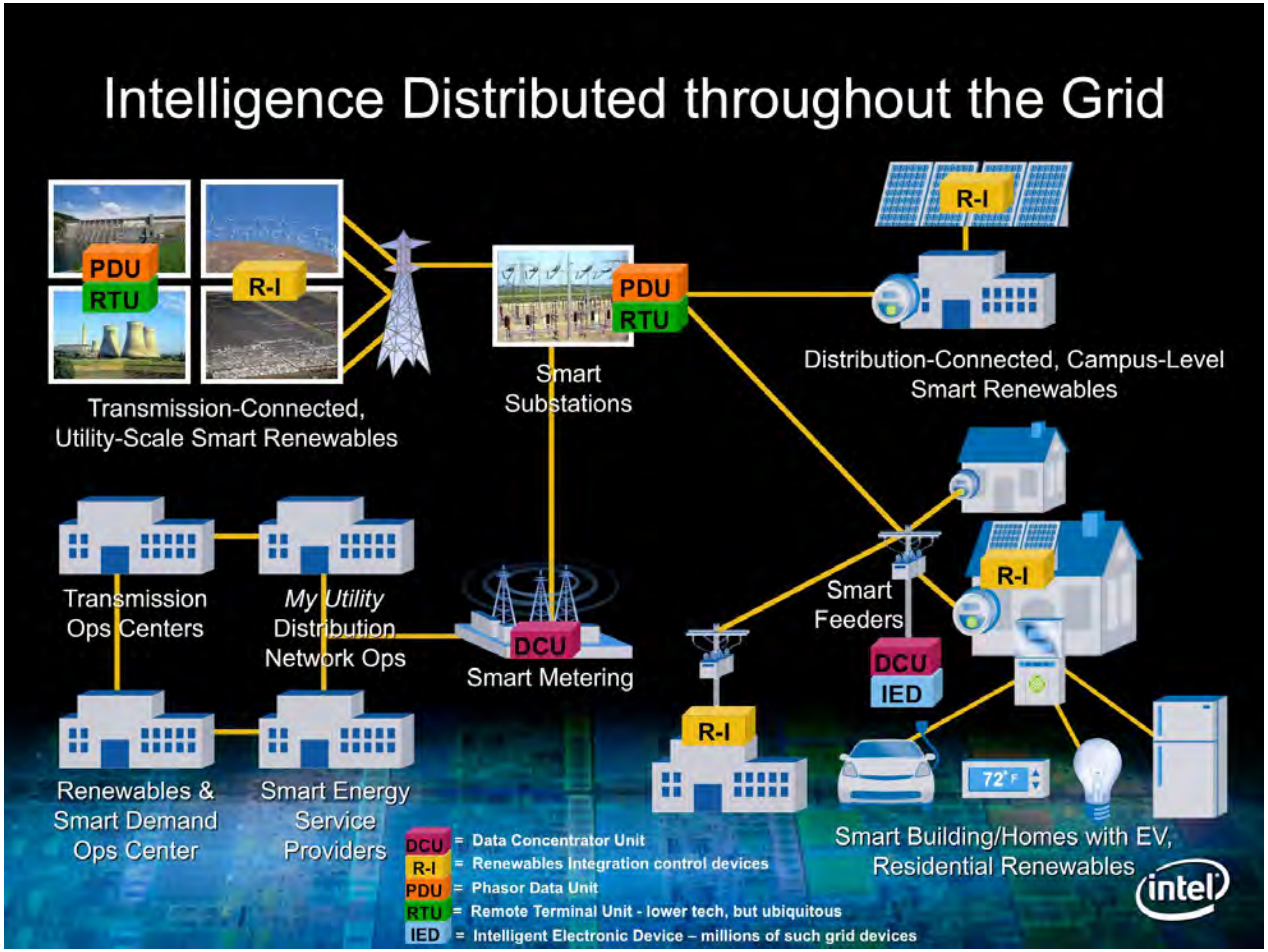


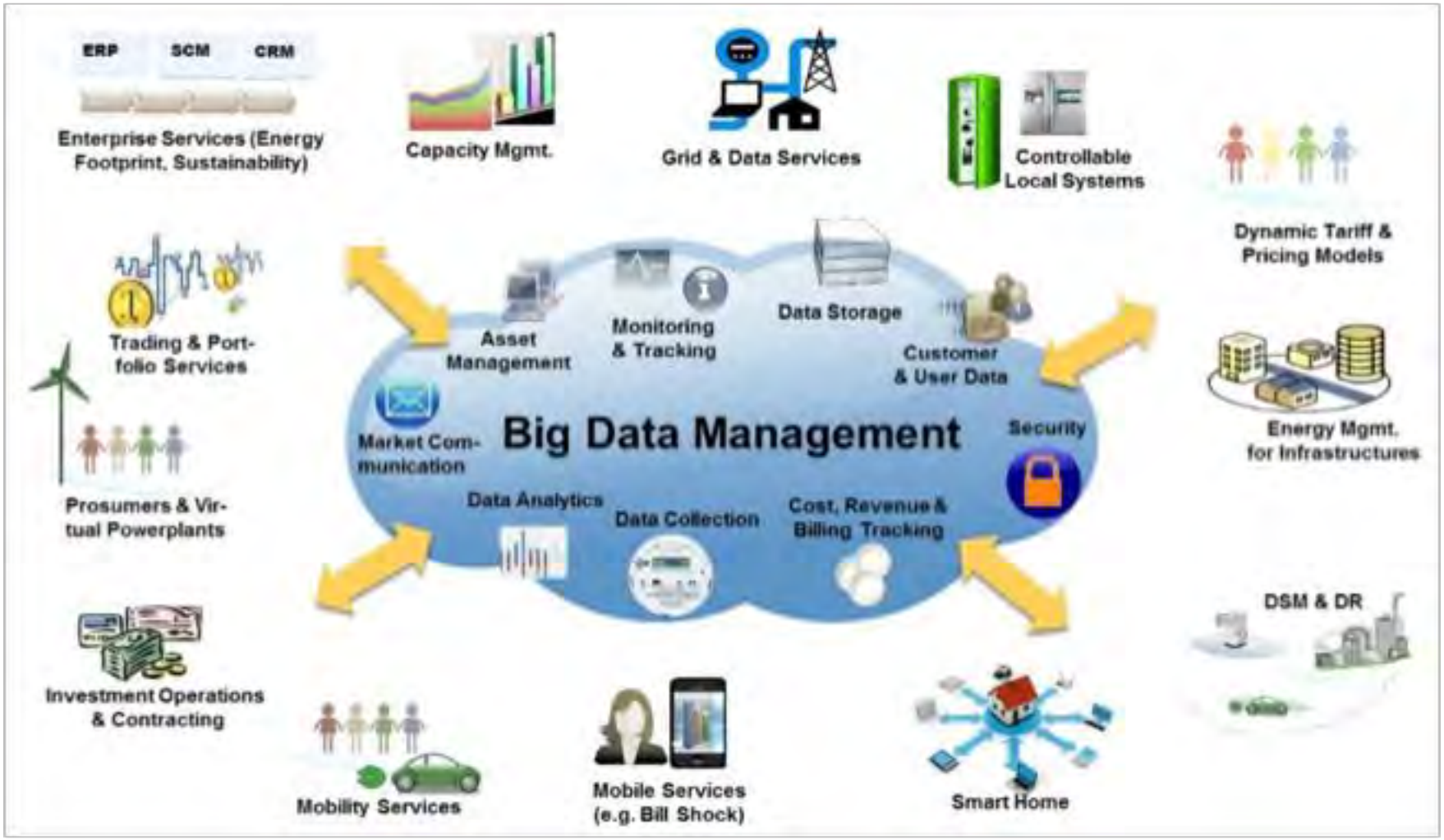

Bulk Power System
DSO
Distribution Planning & Investment
Active Network Operations
Distributed Market Coordination
Distributed Resources
Retail Energy Transactions

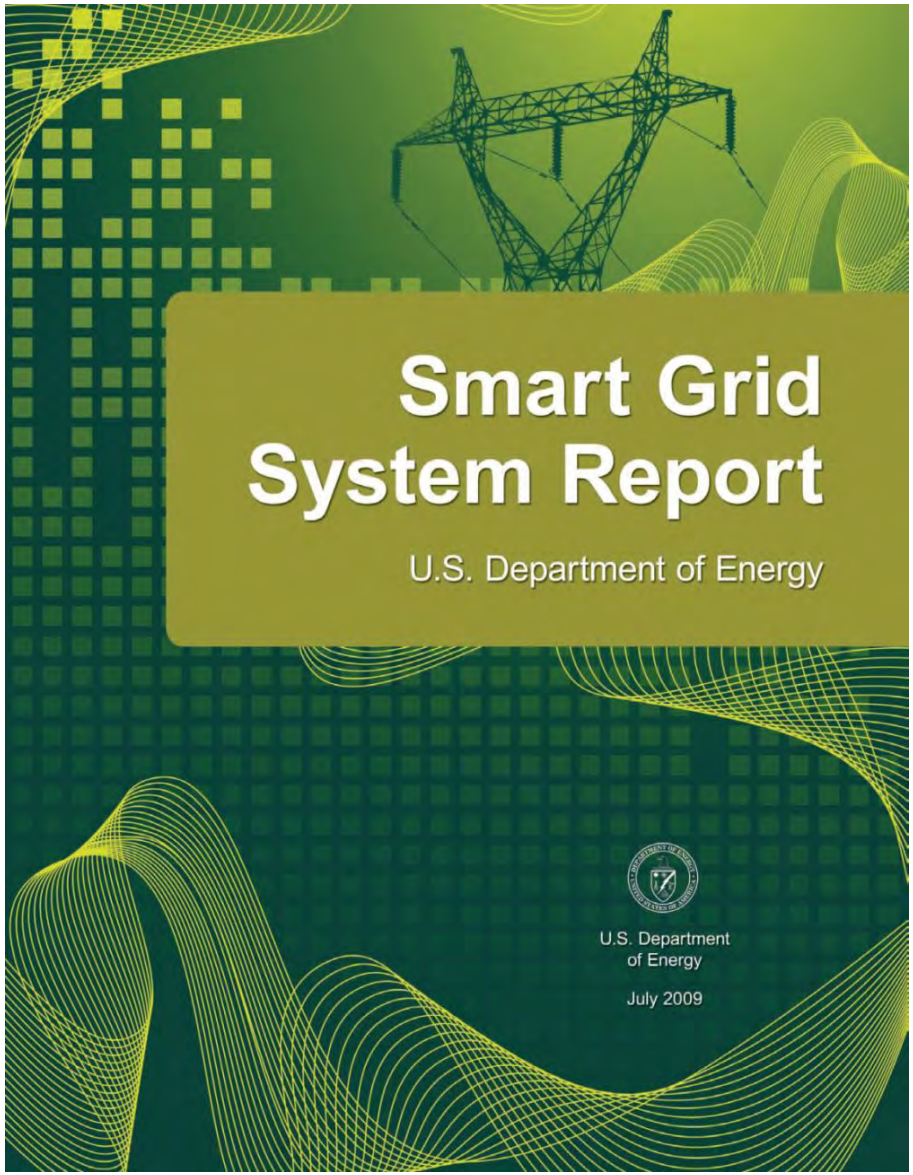
OATI DSO Article

Distribution System Operator Construct Emerges to Address Electric Industry Challenges

Public Utilities Fortnightly – June 2014

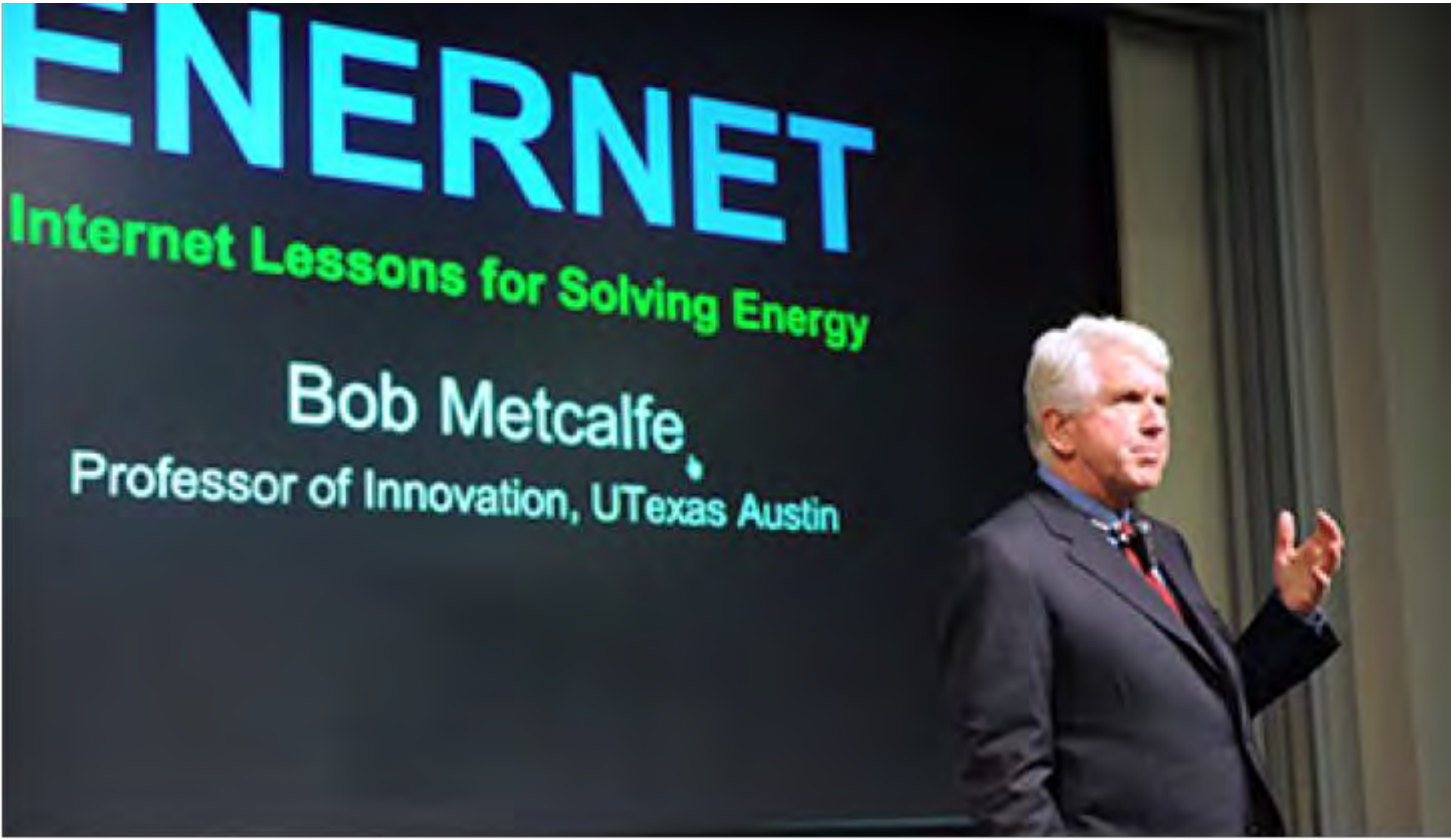

Intelligence Distributed throughout the Grid
PDU
RTU
R-I
Transmission-Connected,
Utility-Scale Smart Renewables
PDU
RTU
Smart
Substations
R-I
Distribution-Connected, Campus-Level
Smart Renewables
Transmission
Ops Centers
My Utility
Distribution
Network Ops
DCU
Smart Metering
Smart
Feeders
R-I
DCU
IED
R-I
Renewables &
Smart Demand
Ops Center
Smart Energy
Service
Providers
72°F
Smart Building/Homes with EV,
Residential Renewables
DCU = Data Concentrator Unit
R-I = Renewables Integration control devices
PDU = Phasor Data Unit
RTU = Remote Terminal Unit - lower tech, but ubiquitous
IED = Intelligent Electronic Device – millions of such grid devices
intel


ERP
SCM
CRM
Enterprise Services (Energy Footprint, Sustainability)
Capacity Mgmt.
Grid & Data Services
Controllable Local Systems
Dynamic Tariff & Pricing Models
Trading & Portfolio Services
Asset Management
Monitoring & Tracking
Data Storage
Customer & User Data
Market Communication
Big Data Management
Security
Energy Mgmt. for Infrastructures
Prosumers & Virtual Powerplants
Data Analytics
Data Collection
Cost, Revenue & Billing Tracking
DSM & DR
Investment Operations & Contracting
Mobility Services
Mobile Services (e.g. Bill Shock)
Smart Home



“ . . . the information networks that are transforming our economy in other areas are also being applied to applications for dynamic optimization of electric system operations, maintenance, and planning .”


FIBER OPTICS



"Over the past 63 years, we met world needs for cheap and clean INFORMATION by building the INTERNET. Over the next 63 years, we will meet world needs for cheap and clean ENERGY by building the ENERNET."

Read These!

A Roadmap to the New Electric Cooperative Business Model

While Some Talk of New Business Models, Iowa's Co-ops Invent Them

The Changing Nature of Rural Electric Cooperatives in the 21st Century

Powering a New Economy: Reclaiming Rural Electric Co-ops

Steve Collier
Director, Smart Grid Strategies

steve.collier@milsoft.com

Twitter: @smartgridman
LinkedIn: linkedin.com/in/stevenecollier