Northwest Low-Carbon Pathways Electricity

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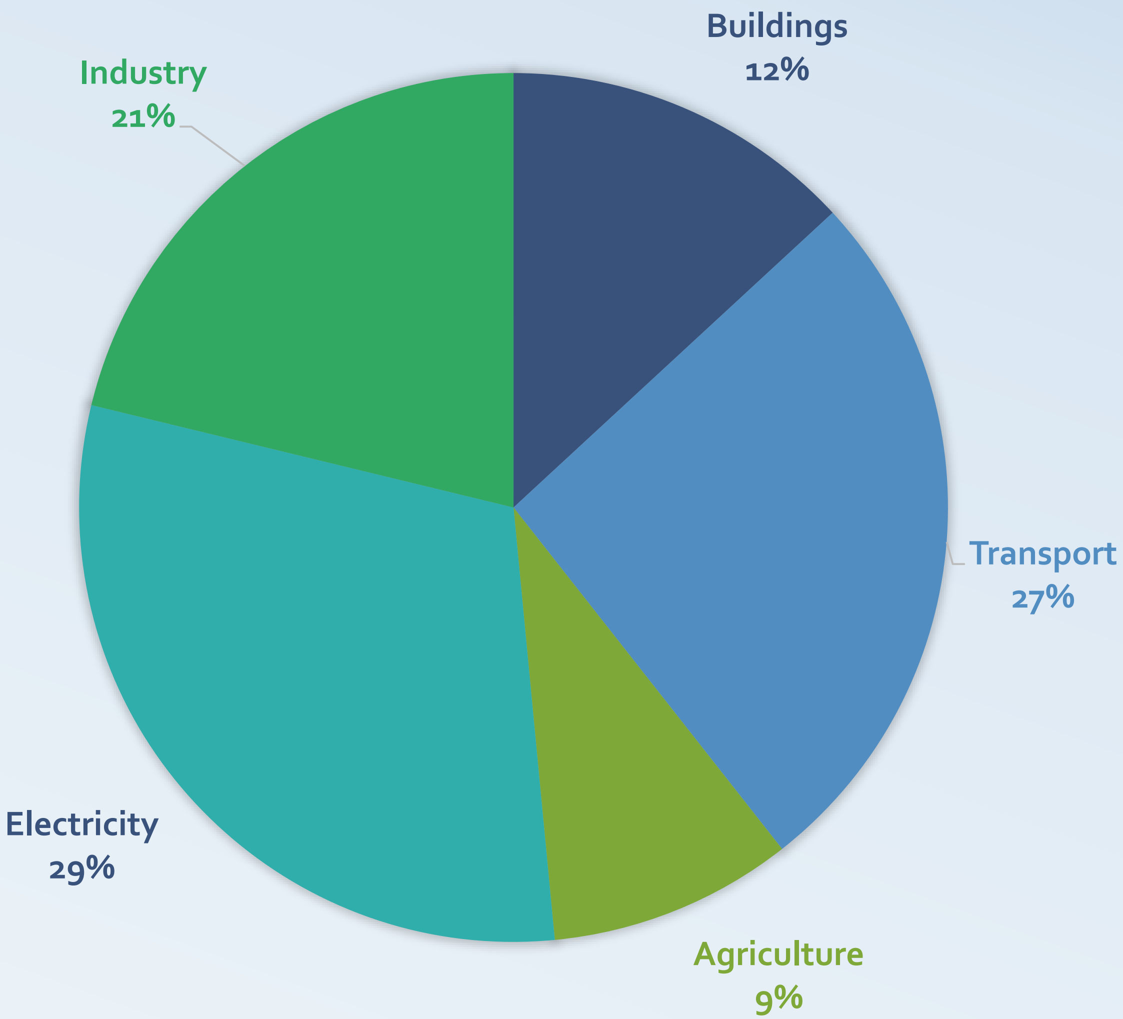
Clean Energy Transition

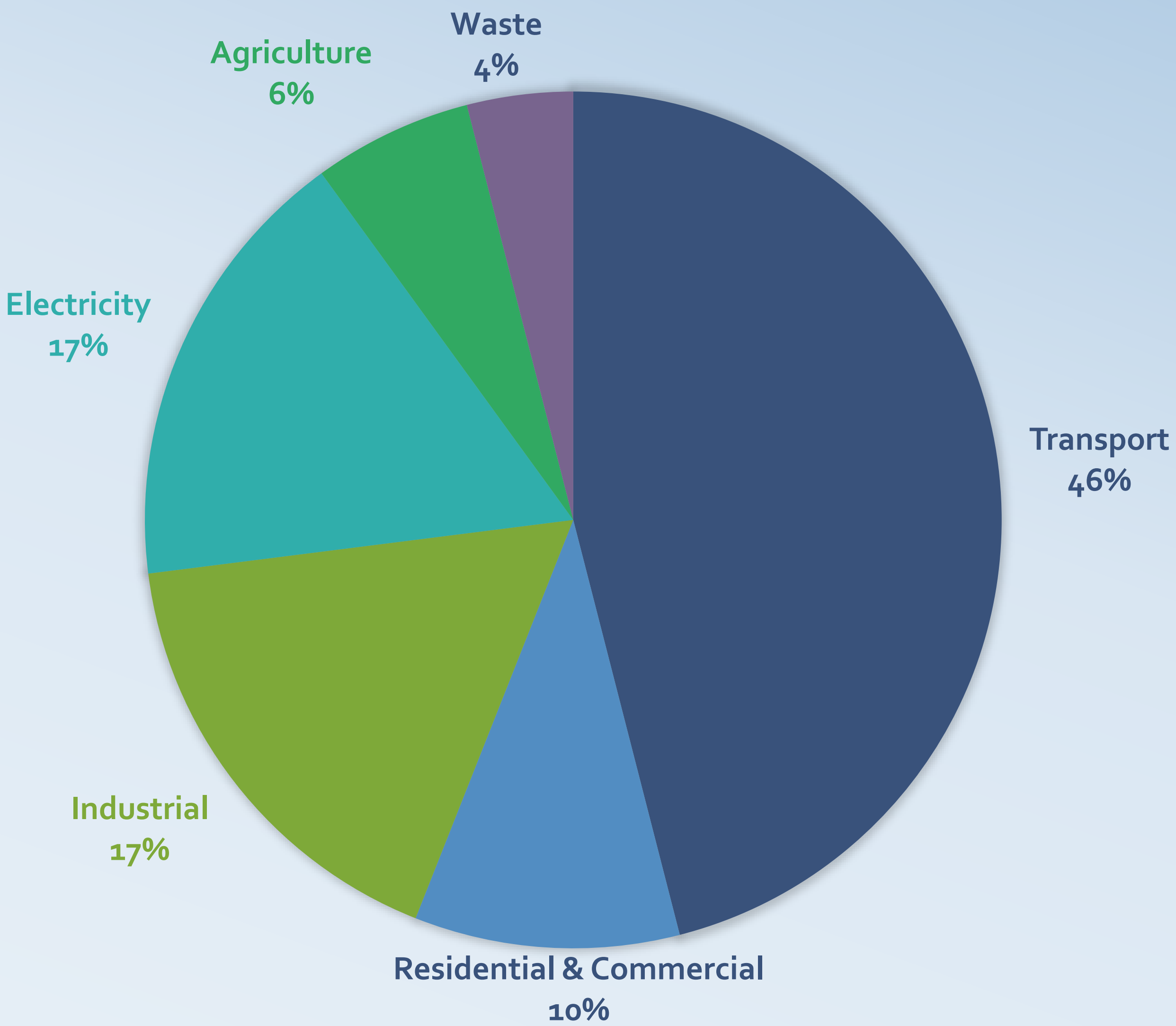
Agenda

- Why electrify everything
- Renewables growth
- Integrating renewables
- Grid redesign & interaction
- Smart grid
- Storage
- Scaling challenges

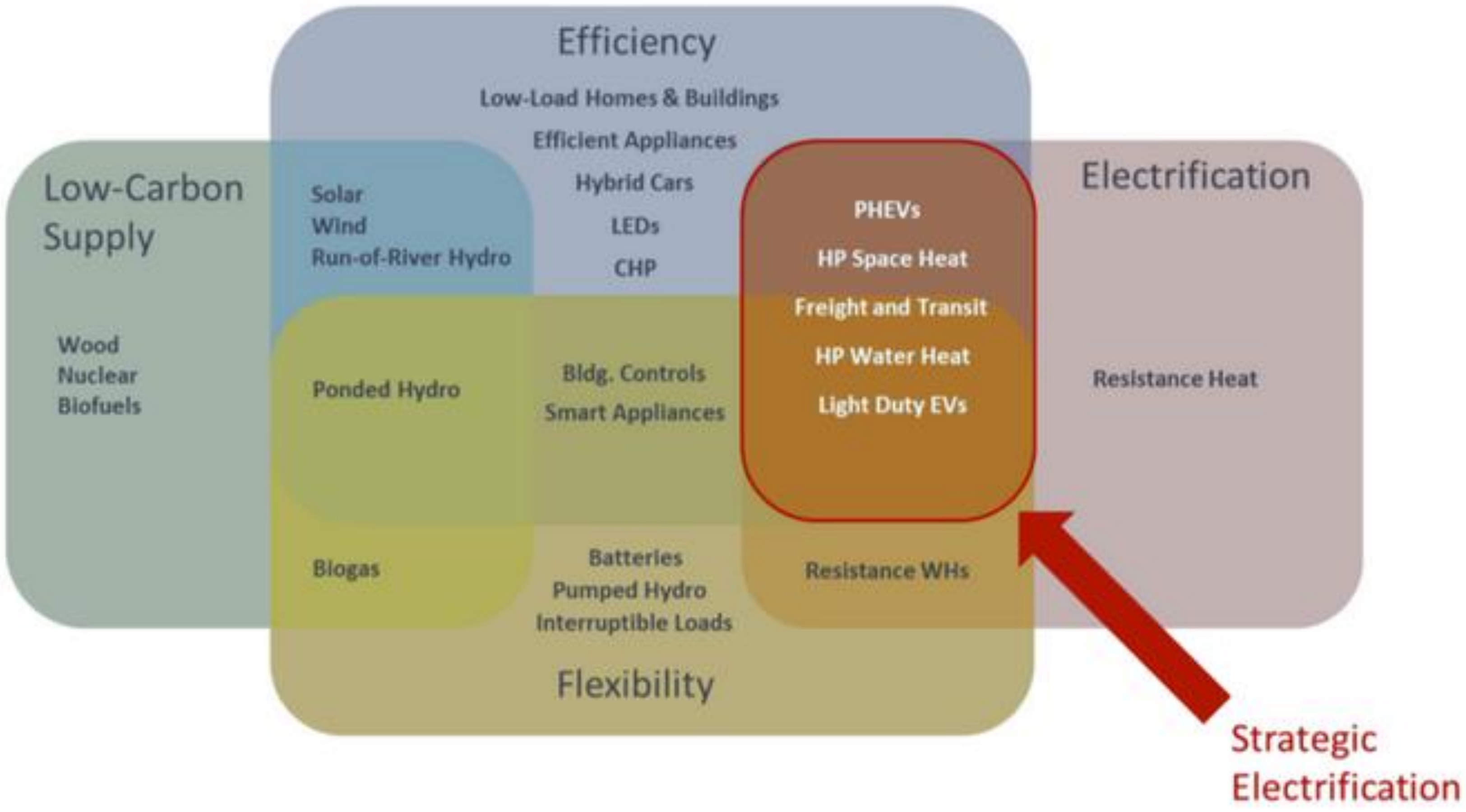
Electrify Everything

U.S. (2014) & Washington (2011)





Strategic Electrification



Strategic electrification in the context of decarbonization. Graphic: Northeast Energy Efficiency Partnerships

Why Electrify Everything?

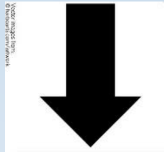
- Global warming consensus
- Growing understanding of the need for a path to zero-carbon electricity

Why Electrify Everything? -2-

- Know how to achieve zero carbon electricity (wind, solar, nuclear, hydro, geothermal, coal/gas with CCS)

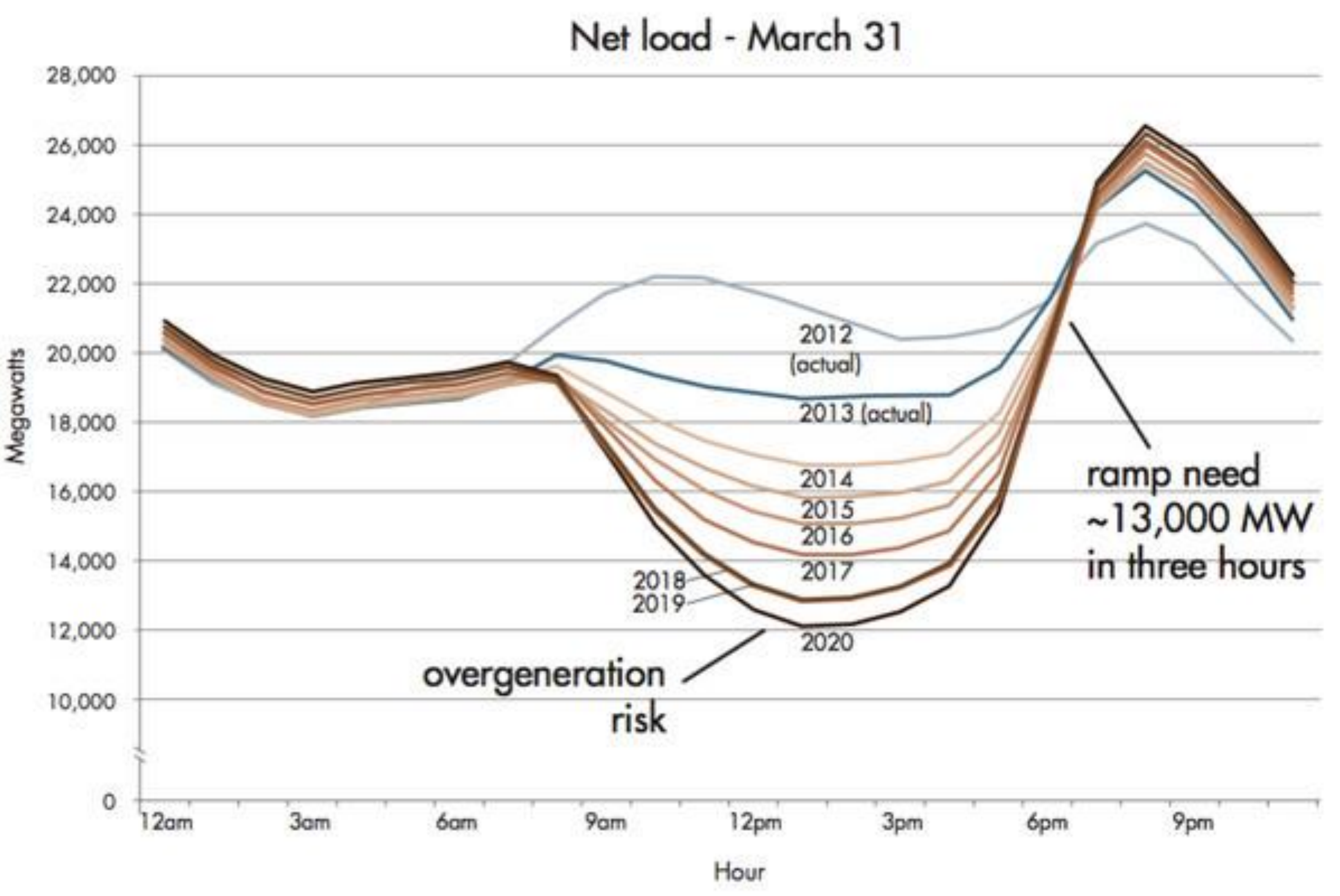
How Clean the Grid is Crucial

- As the grid gets cleaner, whatever is powered by it, gets cleaner
- Profound implications



New Electricity=More RE on the Grid

Figure 2: The duck curve shows steep ramping needs and overgeneration risk



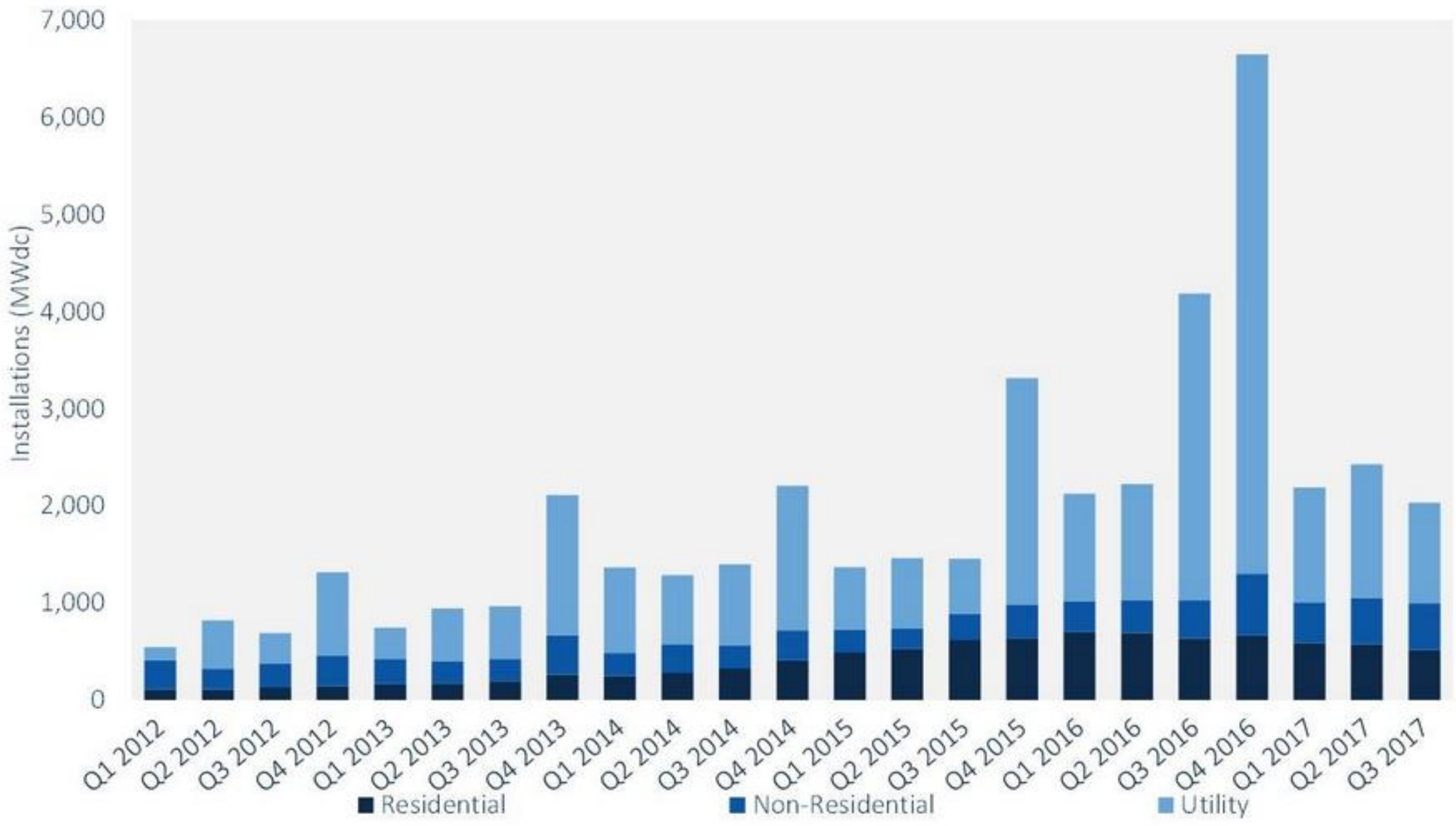
Emissions Efficiency

- Get the same amount of work with less carbon
- Increase load from transportation and building heat; consumption could rise and efficiency could fall, but economy-wide carbon emissions could decline

Renewables Growth

Solar Growth 2012-2017

U.S. Quarterly PV Installations, Q1 2012-Q3 2017

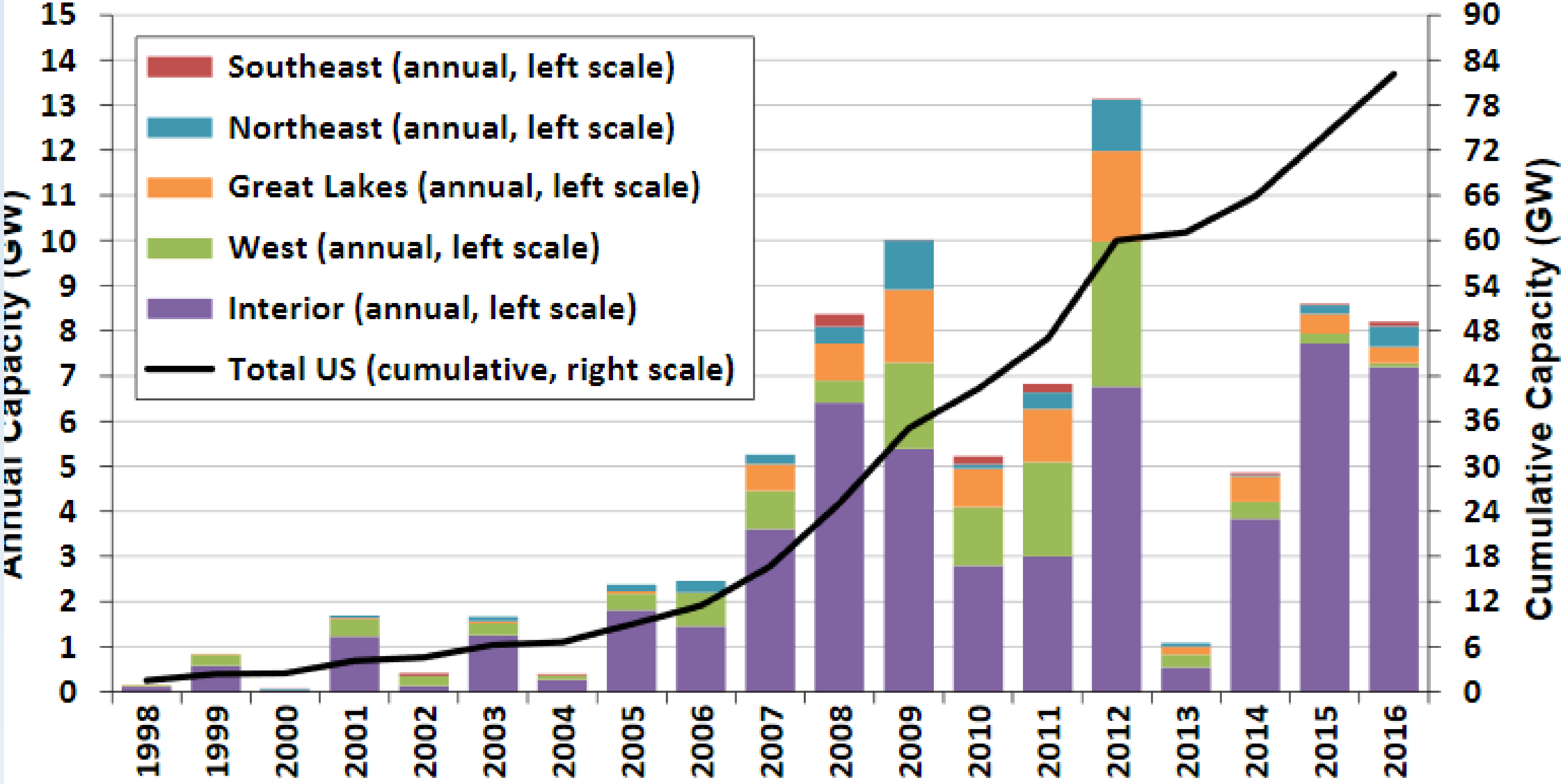


Source: GTM Research / SEIA U.S. Solar Market Insight, Q4 2017

Wind Growth

- August 2017 US DOE released three wind market reports
- Continued growth in wind energy nationwide
- More than 8,200 MW of capacity, 27% of all new energy capacity in 2016
- Supplied 6% of U.S. electricity
- 14 states now get more than 10% of electricity from wind

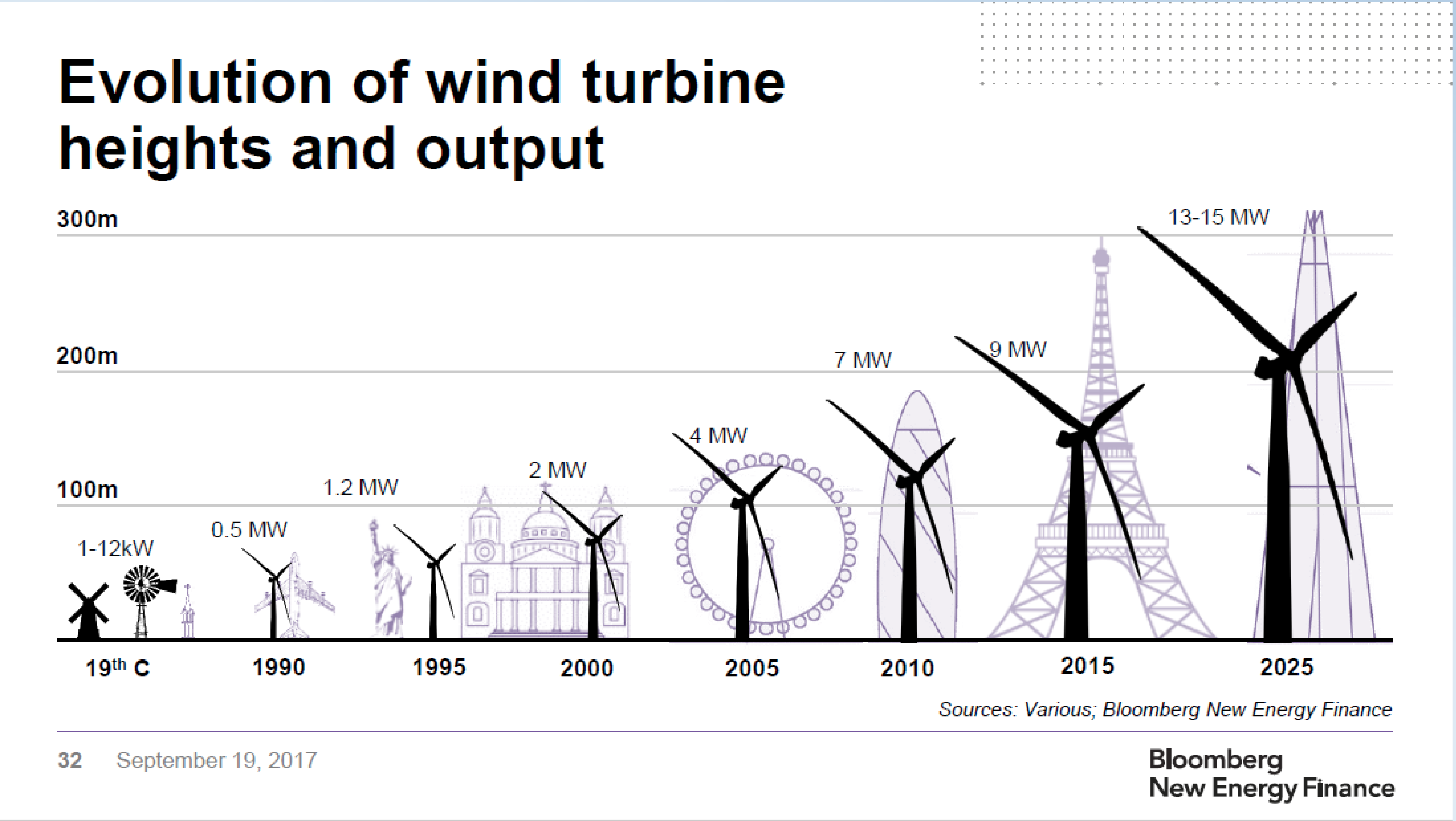
Wind Growth



Source: AWEA project database

Figure 2. Annual and cumulative growth in U.S. wind power capacity

Wind Turbine Efficiencies



Intermittency

- Intermittent vs. predictable power that is dispatchable
- Natural gas, coal, nuclear, and hydro less variable than solar & wind
- Capacity factors for coal-NG 90 %; for wind 22-43% and solar 12-20%

Storage

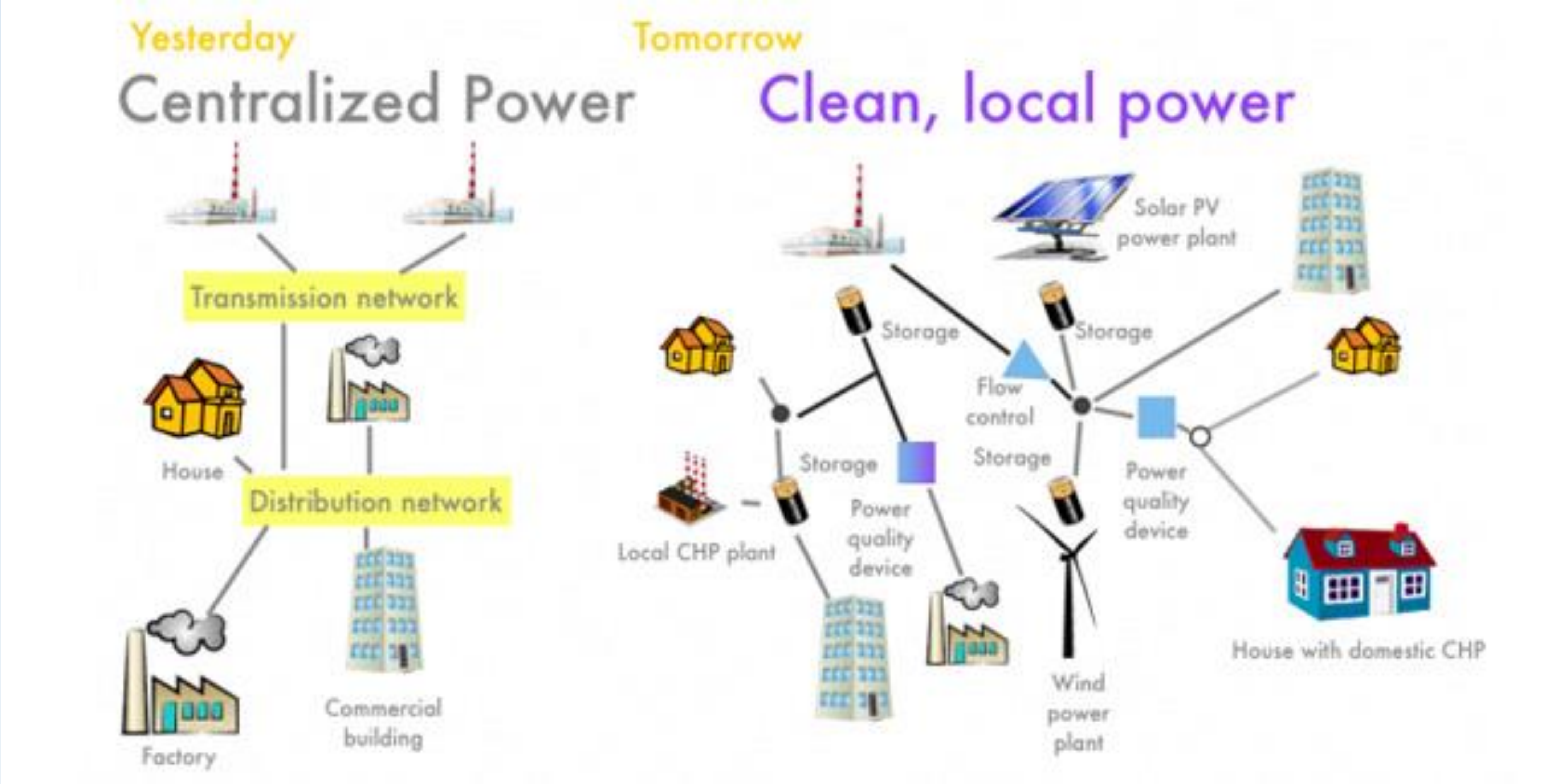
- Amount of energy system can store
- Amount of power system can absorb or deliver
- Energy density
- Carbon footprint of technology
- Energy stored on Investment (ESOI)
- Geologic, hydrogen, batteries

Grid Redesign

- 20th century grid distributed power from large centralized coal, gas, nuclear, and hydro generating plants to far-flung end uses
  - ✓ Track demand patterns with daily peaks
  - ✓ Meet spikes with peaking power generators (NG)
  - ✓ Peaking and redundancy costs and those are passed on to consumer

- 21st century grid accommodate numerous smaller and geographically distributed power inputs, largely variable

Yesterday vs. Tomorrow's Power

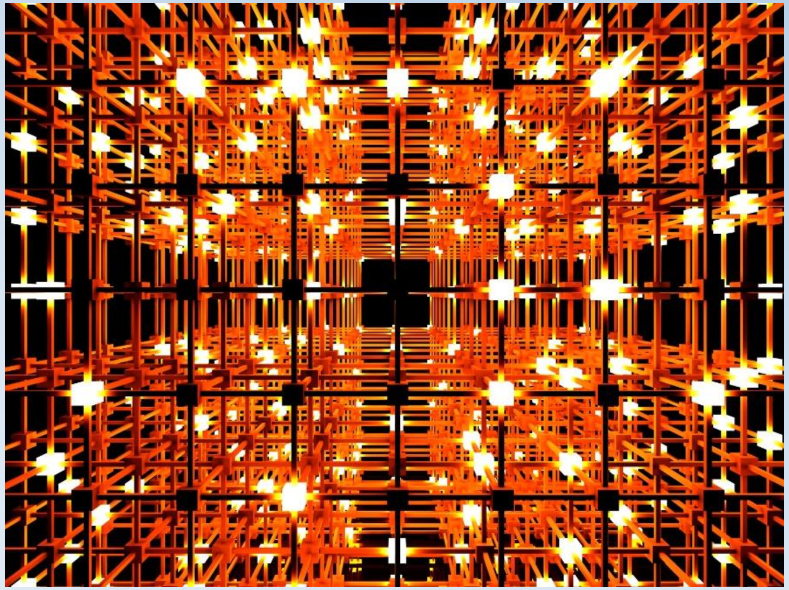


Distributed Generation

- Do away with the centralized grid entirely; generate and store at the community scale
- Challenge for intermittency; needs to be linked
- Decentralizing encourage energy more in line with natural flows of renewable energy
- Communities be more self-sufficient
- Less complex; less vulnerable

Smart Grid

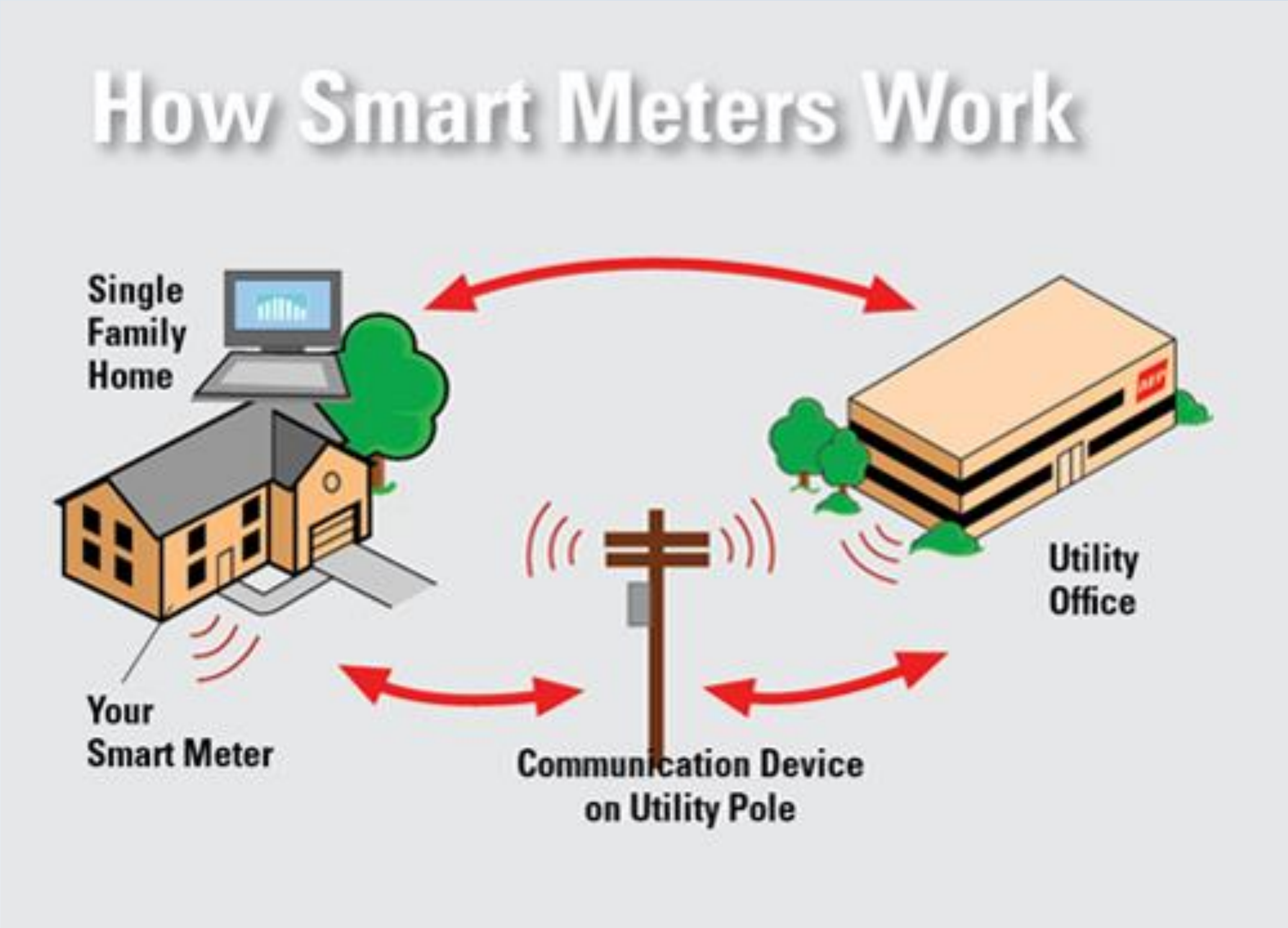
- Set of related technologies to reduce power consumption during peak hours and incorporate grid energy storage
- Both make it easier to integrate wind and solar
- Integrated communications
- Sensing and measurement (smart meters; sensors on transmission network)
- Management and forecasting software
- Additional transmission to balance



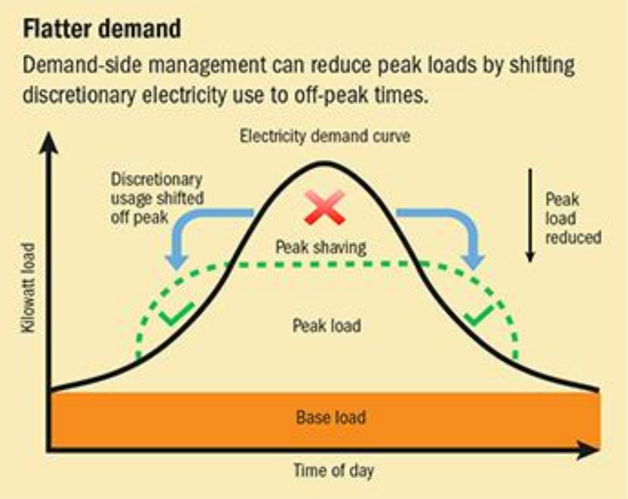
Smart Meters

- Smart meters communicate real-time pricing can shift usage times
- Requires sensors, communications links, software, data management
- Will help reduce times of oversupply or undersupply of electricity and increase affordability
- But must redesign grid
- Internet of Things: appliances connected wifi or hard line, be set to respond to utility co. to adjust usage to price at time

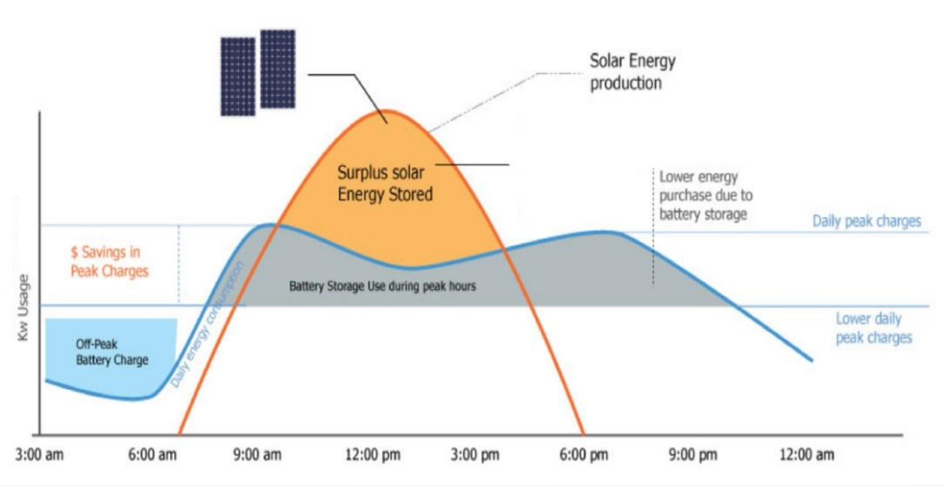
Smart Meters



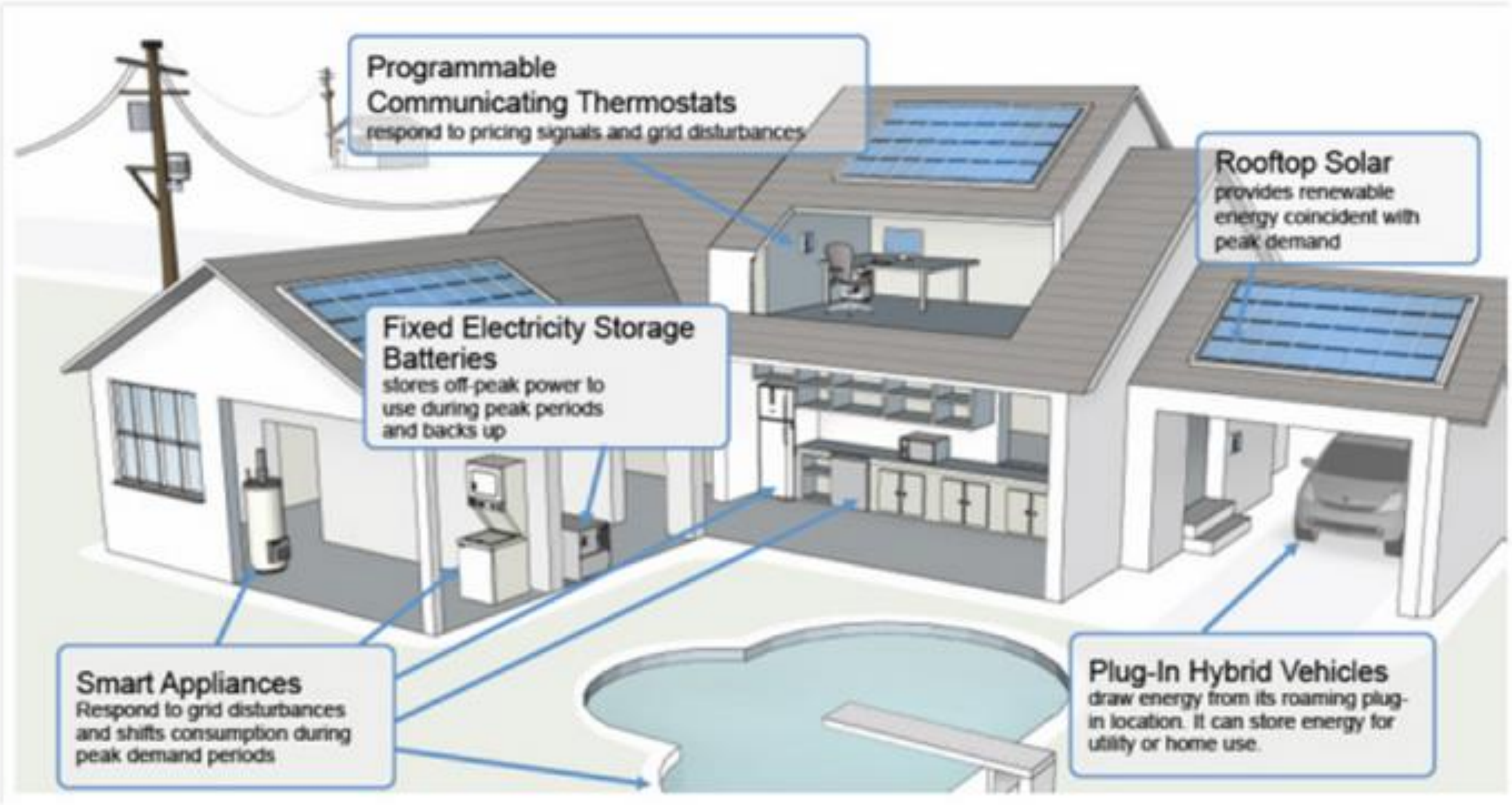
Demand Management



- Geared to when consumers use energy and how much they use
- Voluntary programs; economic incentives
  - ✓ Dynamic pricing
  - ✓ Smart appliances and equipment
- Dynamic pricing: change the price of electricity on hour-by-hour basis
  - ✓ Shift usage to when supplies are abundant and prices low
  - ✓ Have to be able to communicate with users



Grid Interactive Tech in Buildings



An example of "grid interactive" technologies in buildings. Graphic: Digi-Key Electronics

EVs as Storage

- Cars parked an average of 95% of the time
- Leave EV plugged in when electricity could flow to power lines and back
- Decentralized storage of electrical energy
- Throttle charging rate (known as vehicle-to-grid (V2G)
- Need the batteries to get to the stage where they can provide this service

Costs of the Transition

- Tens of trillions of dollars required- where will it come from?
- Retiring all of the fossil fuel plants still in their projected operating lifetimes
- Storage, redundancy, grid expansion, redesign more costs
- How long do we have to subsidize solar and wind?

Scaling Challenges

- Solar and wind financing investment is upfront
- "Fuel" is free
- Maintenance relatively inexpensive
- Not worry about fluctuating fuel prices
- Coal and gas power plants advantage lower tax burden, costs deducted
- Property taxes (solar & wind take up more land)

Scaling Challenges

- Raw materials
- Rare earth minerals for electromagnets in wind turbines and lithium for batteries
  - ✓ 10% annual growth in annual extraction rates, current lithium reserves last 50 years
- Technical potential of wind power
- Location issues
  - ✓ Low-frequency wind noise disturbing people
  - ✓ Solar much real estate for util-scale solar
  - ✓ Habitat species in deserts
  - ✓ Panels washing; concentrated solar needs cooling. Water use where it is scarce

Summary

- Clean electricity mission critical
- Renewables key and growing
- Poses major design issues
- Financial & scaling challenges

Thank you

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Clean Energy Transition

Transitioning from Fossil Fuel to Clean Energy

www.cleanenergytransition.net