Energy Vision: Looking Forward

Anda Ray

SVP, Energy, Environment and External Relations

Forum: "Climate Change, Research and Resources & Reliability"

University of Nebraska

July 13, 2016

- Born in a Blackout

Founded in 1973 as an independent, non-profit center for public interest energy and environmental research

New York City, The Great Northeast Blackout, 1965

Three Dimensions of EPRI's Value

Thought Leadership

Industry Expertise

Collaborative Model

Independent

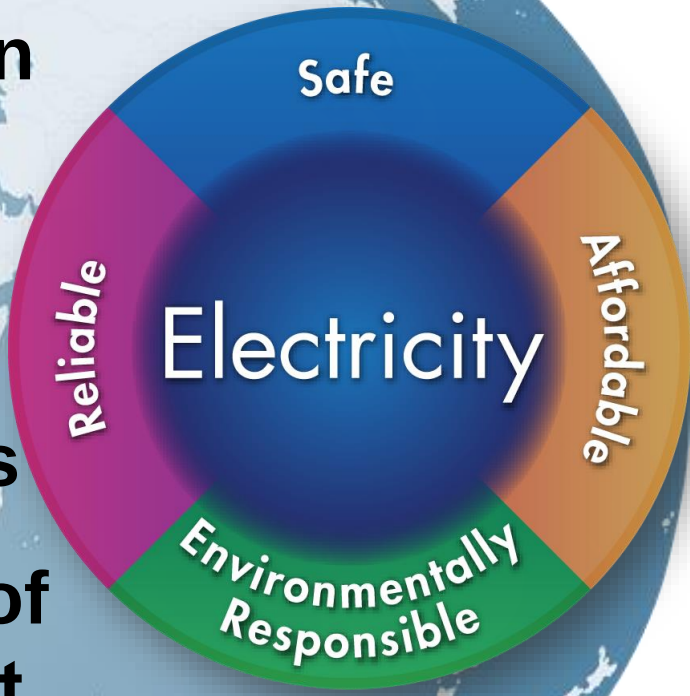
Nonprofit

Collaborative

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Our Members…

- 450+ participants in more than 30 countries
- EPRI members generate approximately 90% of the electricity in the United States
- International funding of 25% of EPRI's research, development and demonstrations

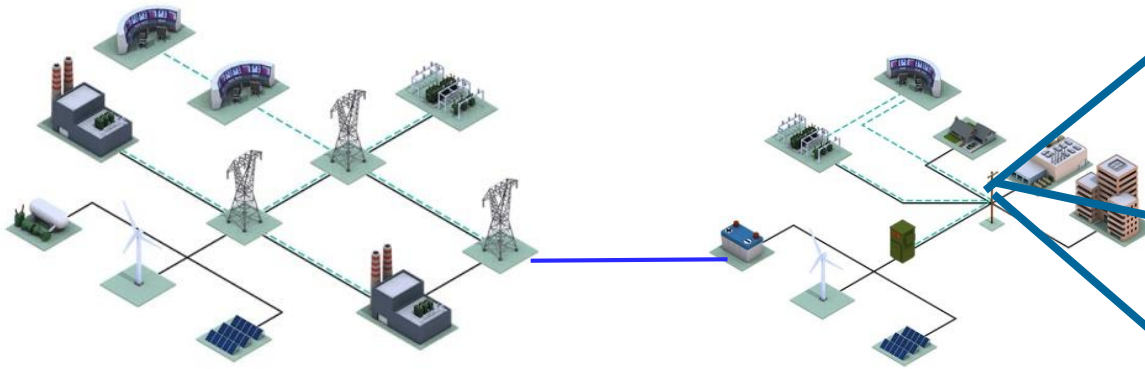


Electricity Sector 1.0 - Yesterday's Power System

Residential

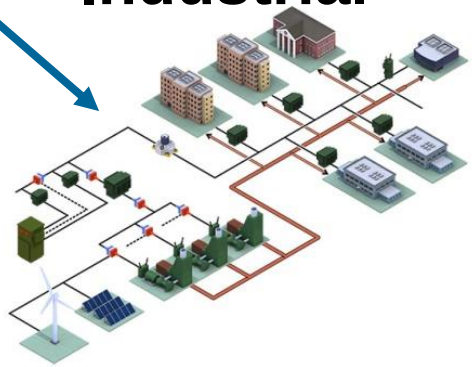
Bulk Power System

Distribution System



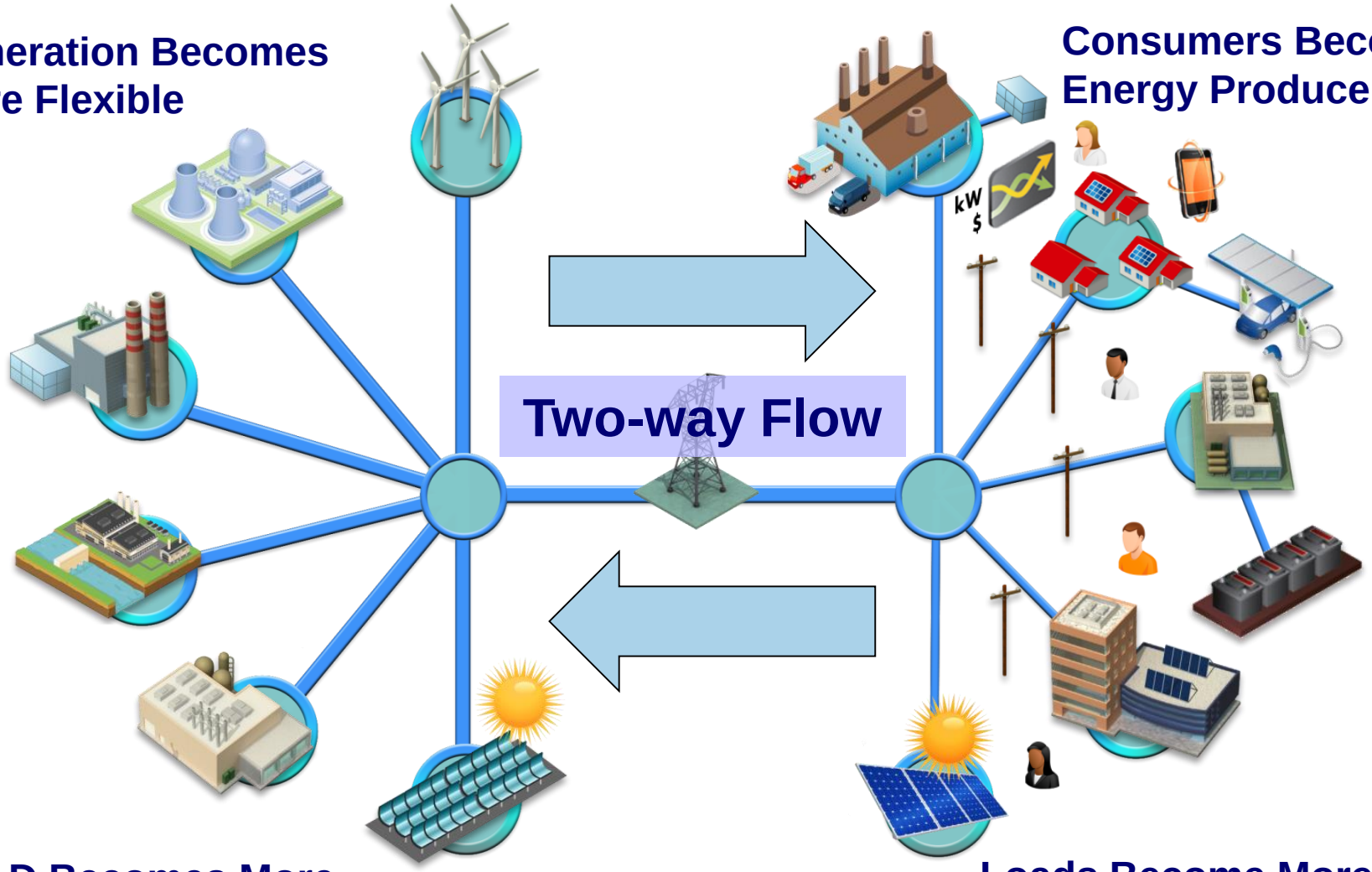
Commercial

Industrial



One Way Power Flow

Electricity 2.0 – Local Resources & "The Integrated Grid"



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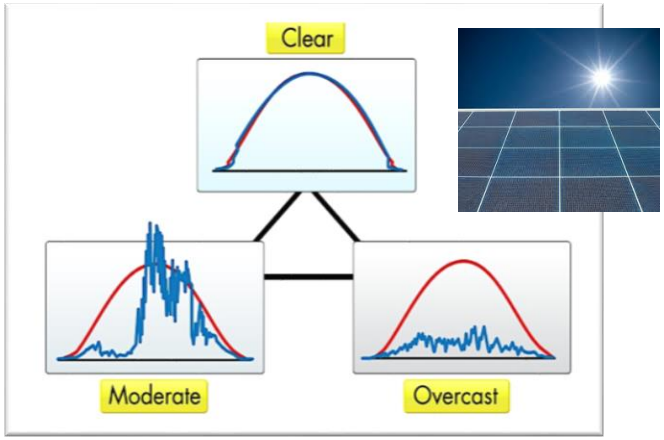
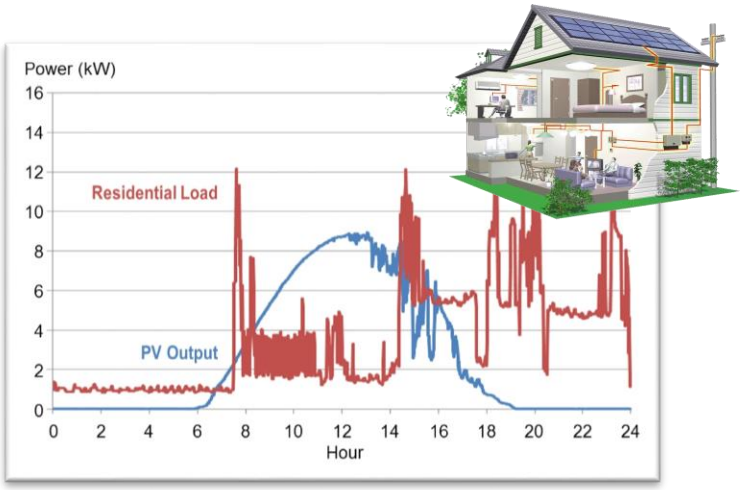
Energy and Capacity

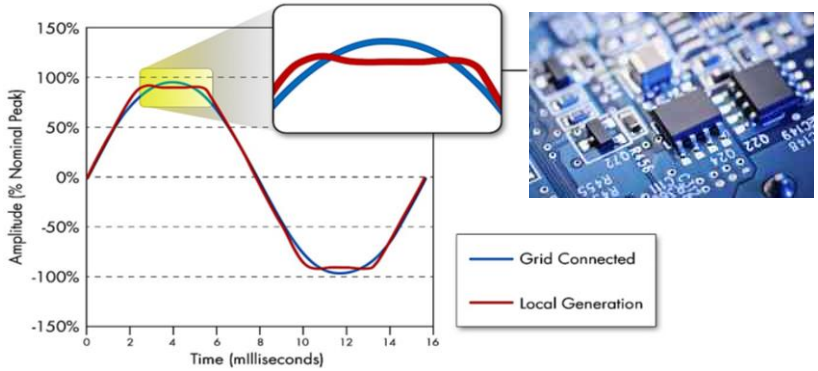
24 by 7 Electricity



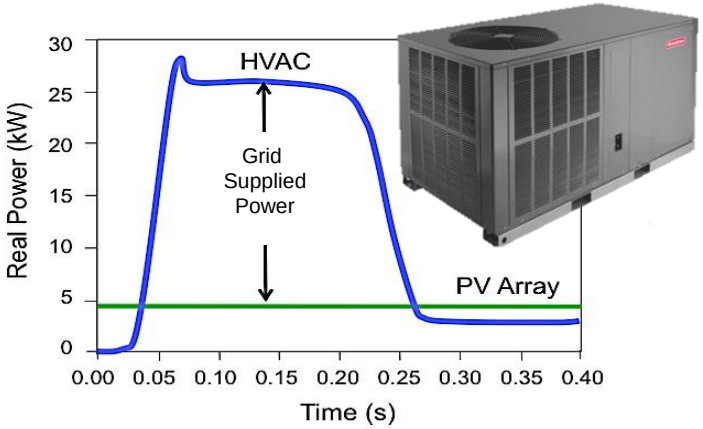
Supply and Demand



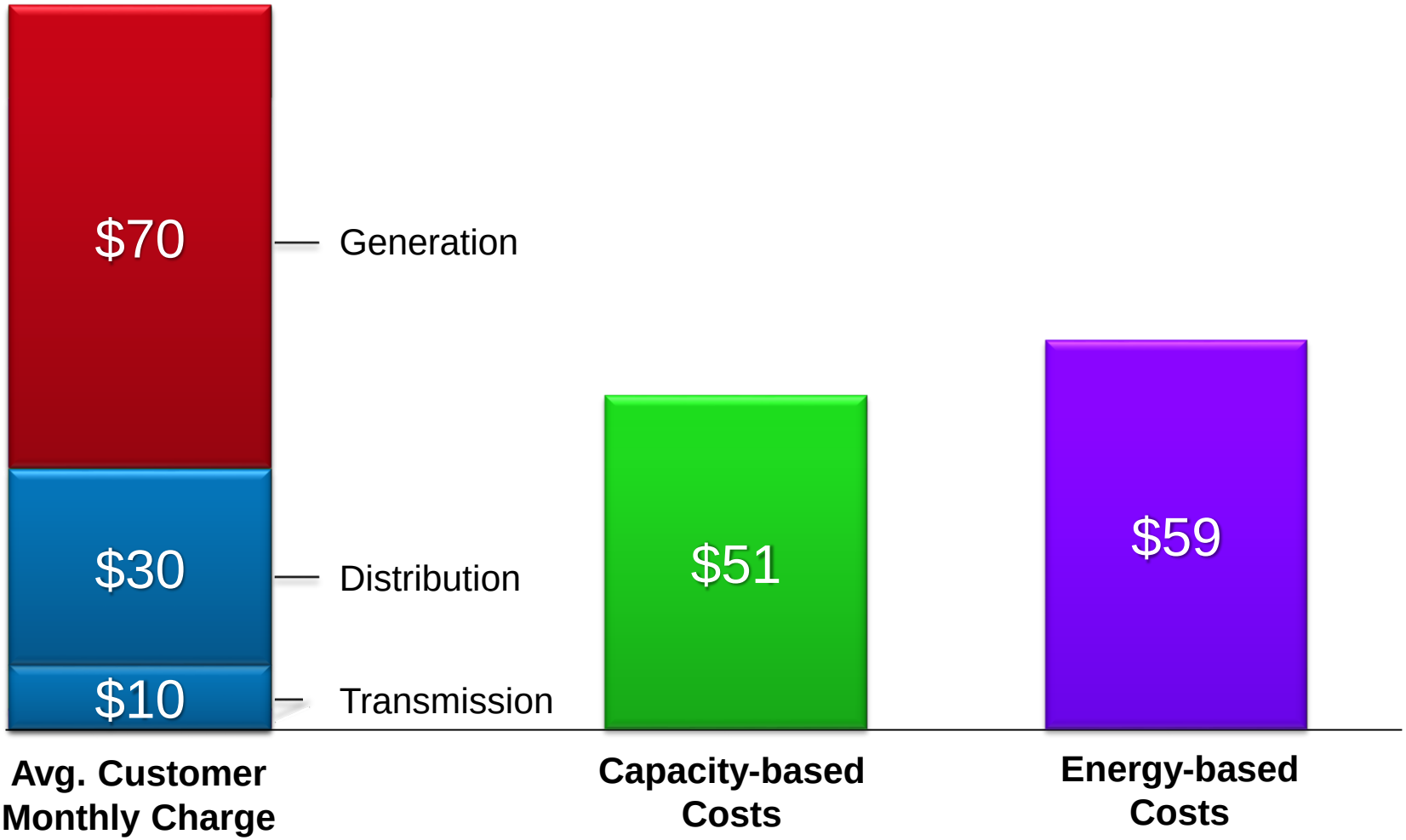
Voltage Quality



Startup Power



Energy (Mwh) and Capacity (MW) – The Cost of Grid Connected Services



Generation (Energy/Fixed Cost) breakdown based on PJM market analysis (2011)

T&D (Fixed/Variable) cost breakdown based on current SCE Implied Cost Estimates (source: E3)

Electricity and Energy 3.0 – Connected "The Internet of Things" - Services and Devices

Convenience, Comfort, Choice, Control…Cost-Effectively

195 Nations Adopt First Universal Climate Agreement At COP21 Talks In Paris – December 12, 2015

(left to right) ***UN climate chief Christiana Figueres; UN Secretary-General Ban ki-Moon; French Foreign Minister and president of the COP21 meetings Laurent Fabius; French President Francois Hollande,***

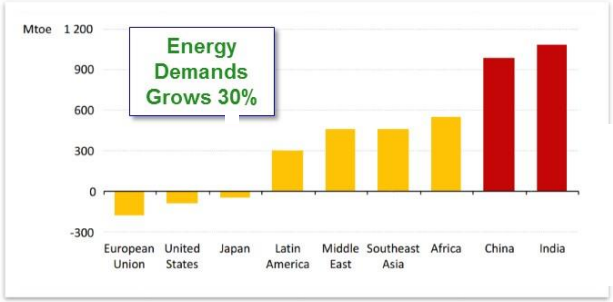
Essential Elements of the Paris Climate Agreements

"Should" not "Shall"

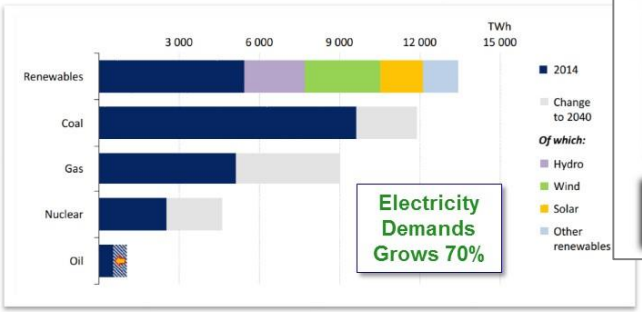
1. Each Country/Party submits "Nationally Determined Contributions" (NDC) & Measures
2. "Common but differentiated responsibilities and respective capabilities" (Best Effort)
3. Update NDCs at common 5-year intervals toward 2050 goals
4. Establish a central project crediting mechanism (Kyoto Protocol)
5. Establish a "Transparency and Accountability" framework
6. 5-year "Stocktaking" – progress on mitigation, adaptation and finance
7. Reduce Climate "vulnerability" and increase Climate "resiliency"
8. Establish a mechanism for "loss and damage" assessment (Warsaw Int'l mechanism)
9. Developed countries committed to $100 billion/year by 2020 (public & private funds)

Energy and Emissions

ENERGY: Smarter Global Demand and Use of Energy



Increased Energy Demand, 2014-2040



Increased Electricity Demand, 2014-2040

EMISSIONS: Global Focus on Economy-wide Emission Reduction

Large Corporations Curbing Carbon Emissions

Coca-Cola, Microsoft, intuit, Sun microsystems, SONY, CISCO

Certification Standards

The Gold Standard – Premium quality carbon credits

VCS Verified Carbon Standard – A Global Benchmark for Carbon

Clean Development Mechanism

CCX – Chicago Climate Exchange

Green-e

International Agreements

Kyoto Protocol (1997)

G8 Leaders (2009)

COP15 – Copenhagen Accord (2009)

U.S./China Statement (2014)

COP21 – Paris Agreement (2015)

ELECTRICITY: grows faster than total energy

Global Focus: Smarter Energy with *Significantly* Reduced Emissions

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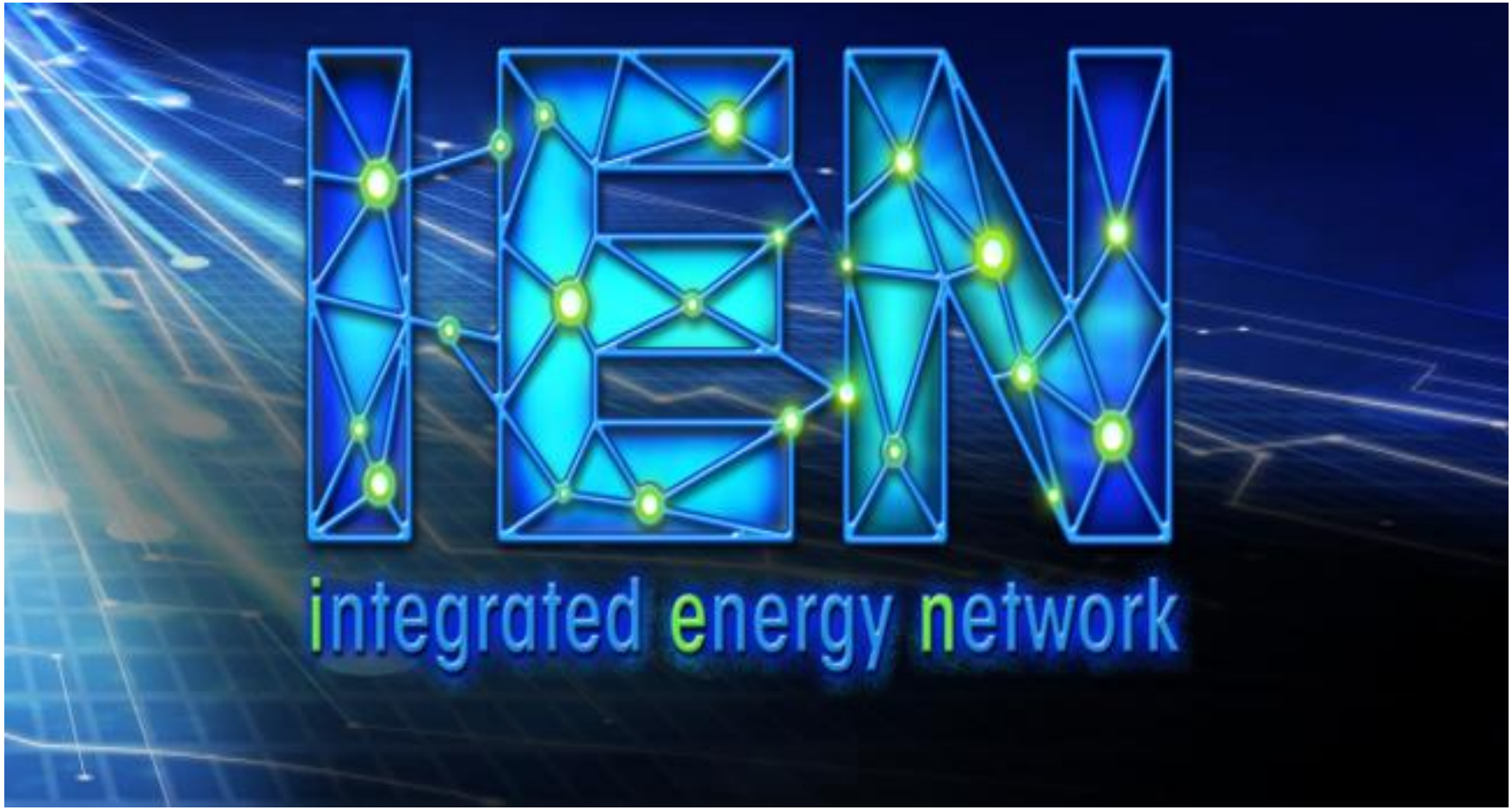
EPRI Scenario Outcomes: “Global Points of View”

- Energy and Environment Priorities
- Efficiency and Renewables Increase
- Customer Choice and Expectations Grow
- Connection Across the Economy Increases
- Innovation and Surprises Will Come

Energy 4.0 - Vision of the Future - “Integrated Energy Network”



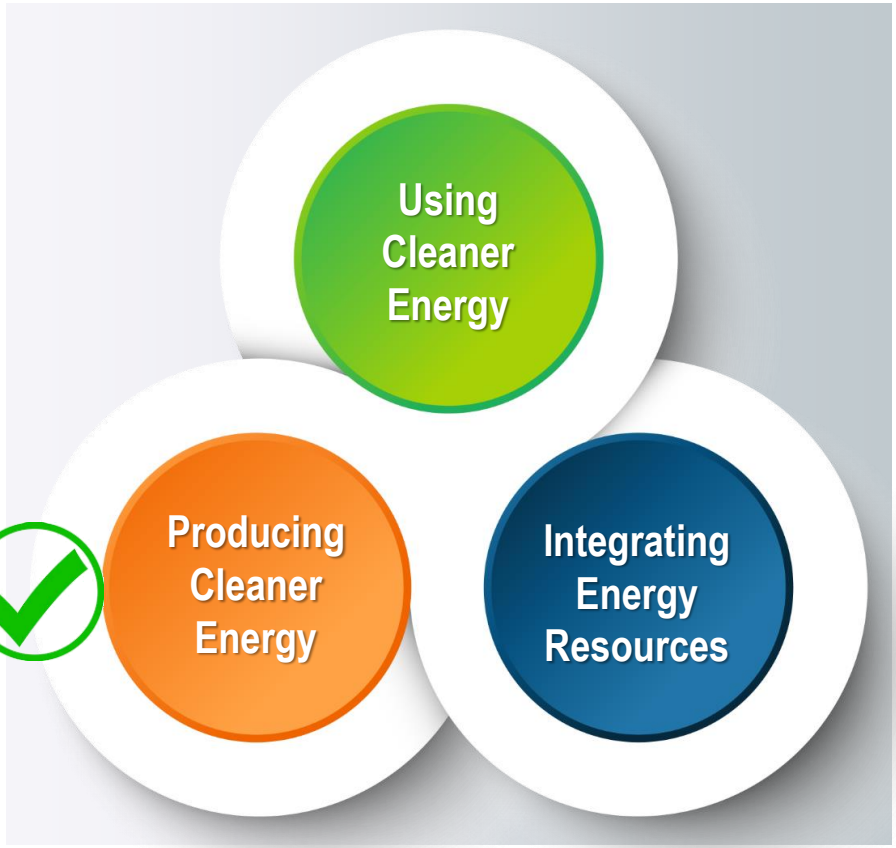
WHY?

“Integrated Energy Network” - Three Evolving Infrastructures

“Integrated Energy Network”

A Network of Infrastructures that connects customers with clean energy production and use

A Look Ahead - I. Producing Cleaner Energy



"Reducing emissions from the production of electricity and other forms of energy"

Transition to Cleaner Electricity Generation ~2030

Renewables

Distributed Energy Resources

Ultra Supercritical

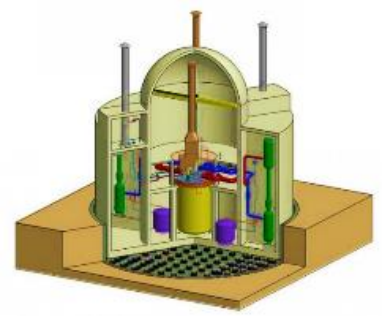
Renewable Growth will be Global

Pace and Scale of Nuclear, Coal and Natural Gas will vary from Region to Region

Natural Gas

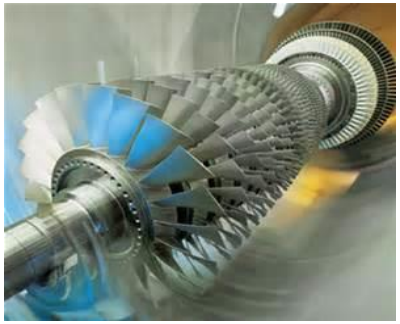
Nuclear

Pathway to Cleaner Electricity/Energy Generation ~2050



Generation IV Nuclear
(co-production – electricity, hydrogen steam)

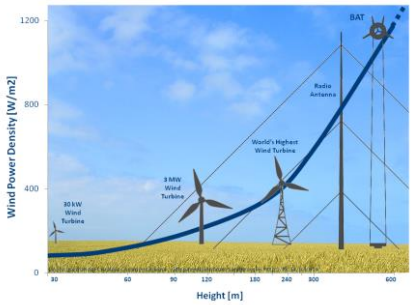
Large-Scale Storage



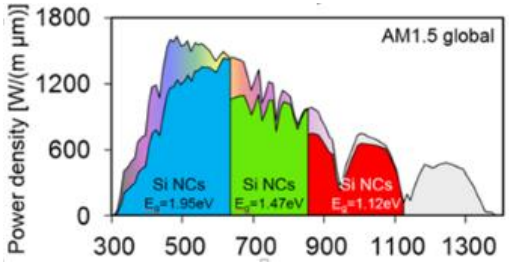
Advanced Power Cycles
(e.g., Supercritical CO_2 Cycle)

Coal and Gas Carbon Capture and Sequestration

Technology innovation in the next decade will be key to ensure all options for cleaner energy production are available in the long term

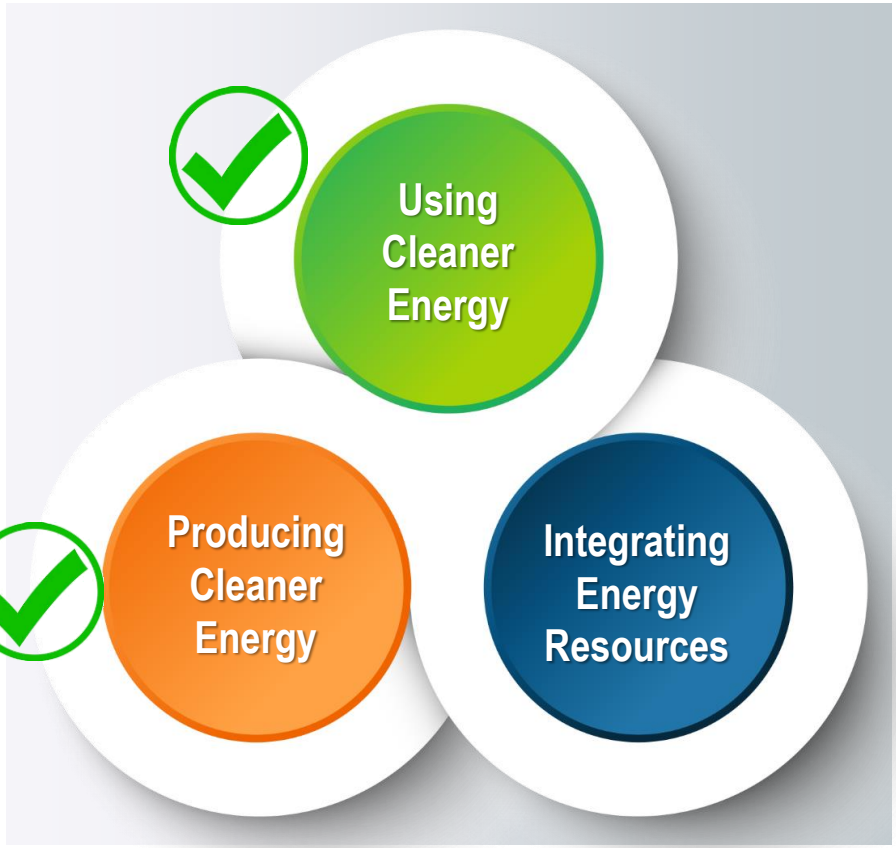


High Altitude/Power Wind



Gen III Photovoltaic (PV)

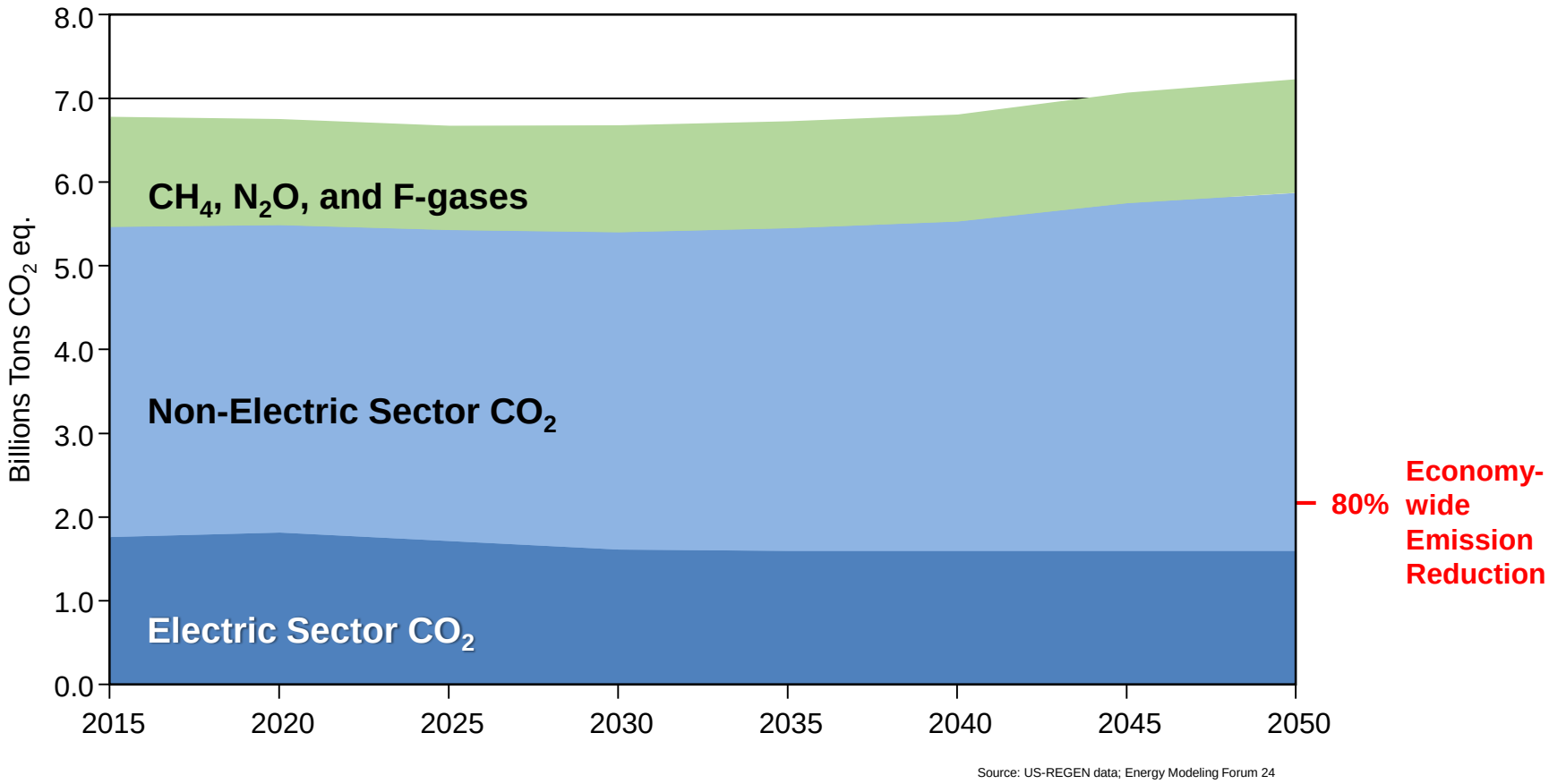
A Look Ahead – II. Using Cleaner Energy



"Electrification Enables other Sectors of the Economy to Decarbonize "

U.S. Economy-wide Emissions

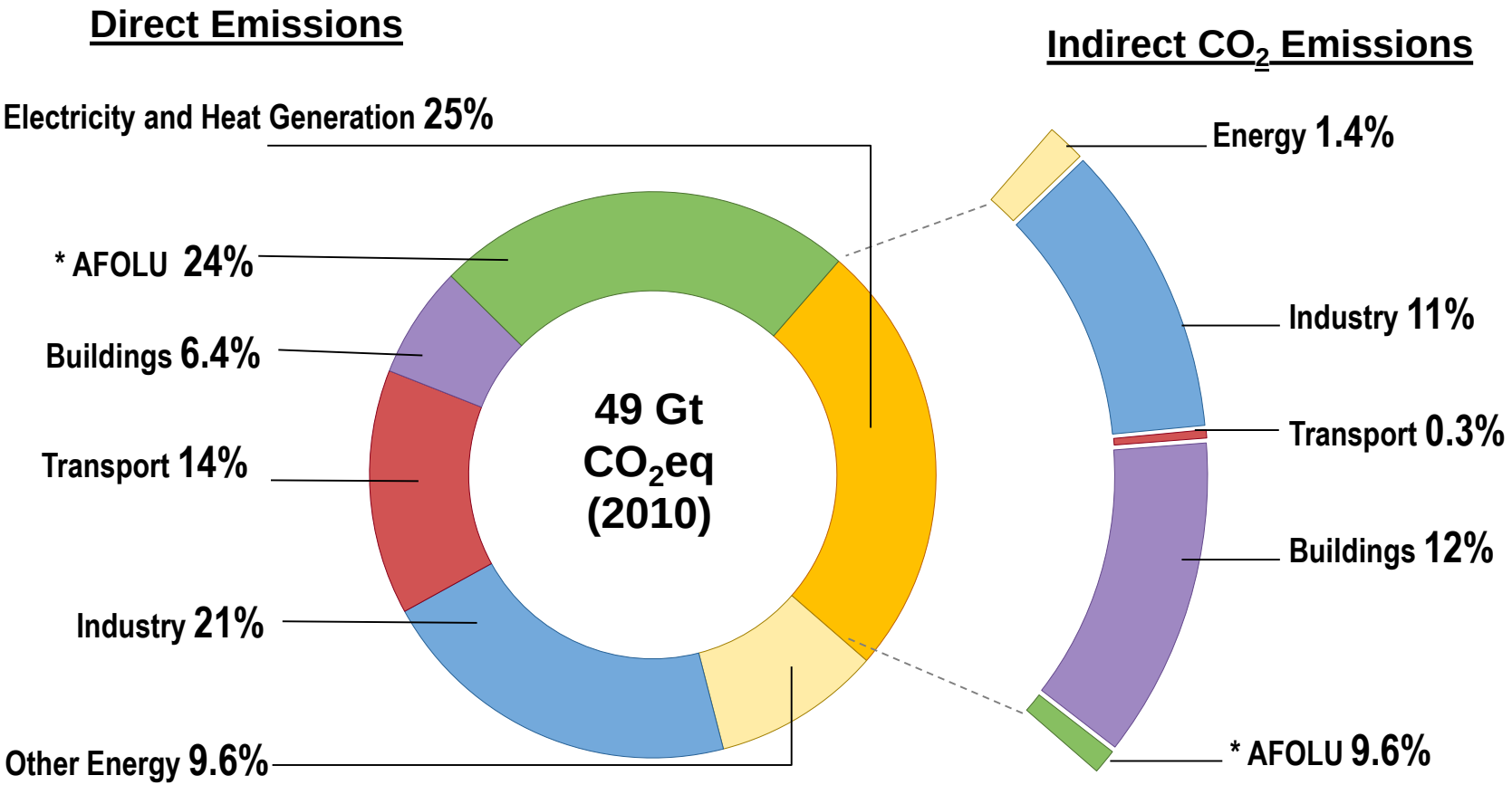
Example Scenario



Source: US-REGEN data; Energy Modeling Forum 24

Clean Electricity Enables Economy-wide Emission Reduction

Global *Economy-wide* Emission



Cleaner electricity:

- **Reduces indirect emission and direct emissions**
- **Enables production of other clean energy to further emissions**

Source: Contribution of Working Group III to the Fifth Assessment Report of IPCC, Pg. 9.

* Agriculture, Forestry and Other Land Use (AFOLU)

Using Cleaner Energy

One Example of Efficiency and Electrification to Reduce Emission

Single-Family Home

Energy Efficiency Improvements

Heat Pump

Replaces Gas Furnace

PHEV/EV

Replaces Mid-Size Car

Transition to Using Cleaner Energy ~2030

Electric Vehicles

Advanced Energy Communities

Industrial Processes

Rail Electrification

Heat Pumps

Pathway of Cleaner Energy Use ~2050

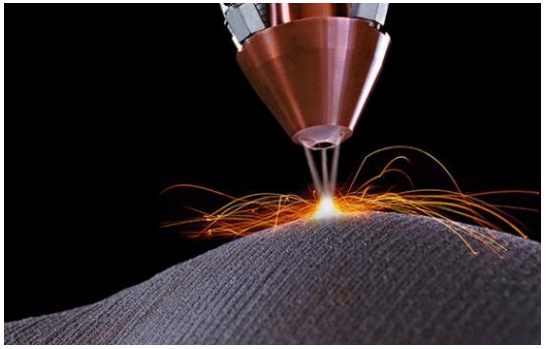
Hydrogen

Transportation Electrification

Teleheating

Bioenergy

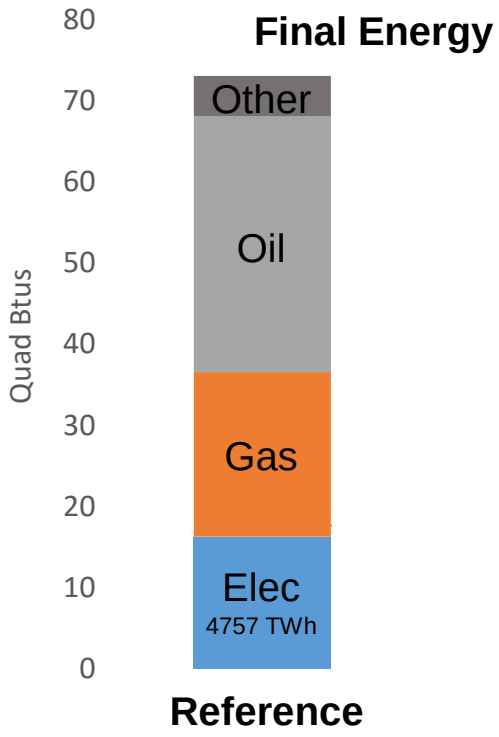
Indoor Agriculture

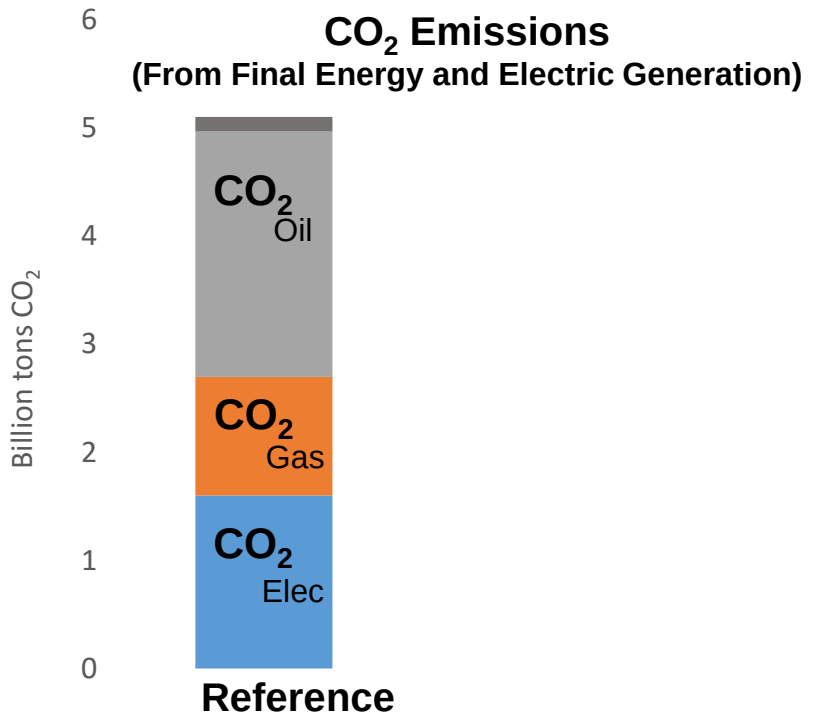


Advanced Manufacturing

EXAMPLE: Assume U.S. 70% Emission Reduction by 2050

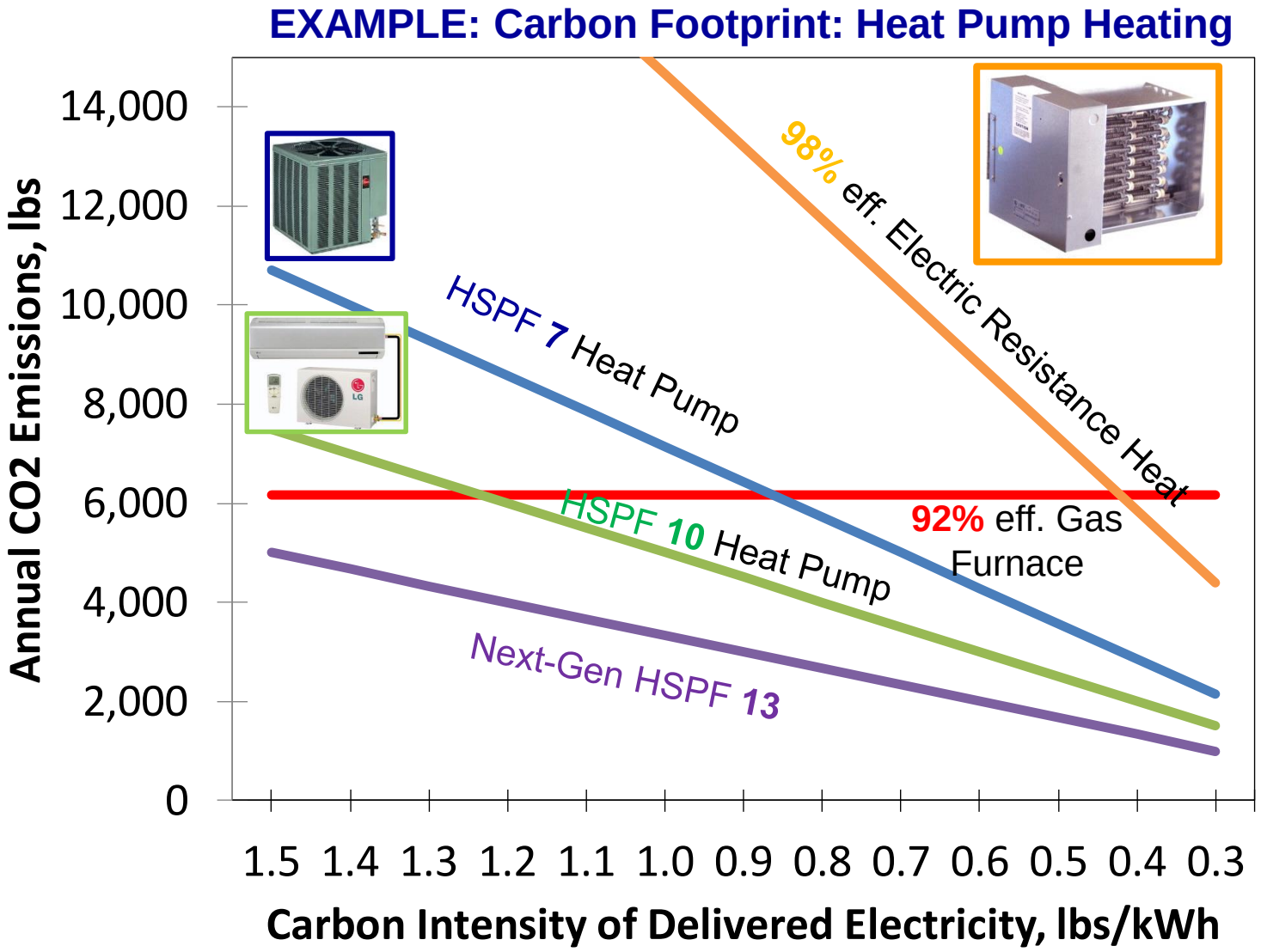
Example Scenario



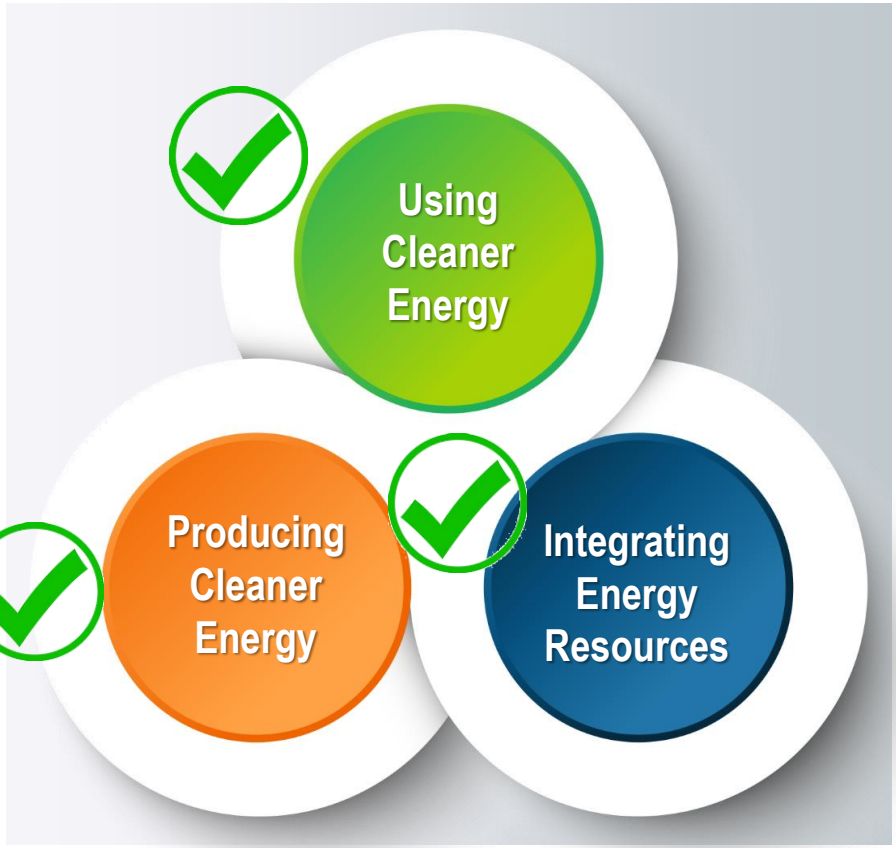


Efficiency and Electrification Key to Emission Reduction

“The Gift that Keeps on Giving” – Electrification



A Look Ahead - III. Integrating Energy Resources



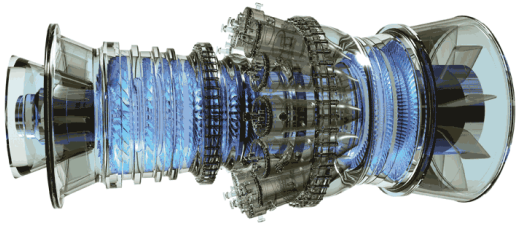
"The Integration of Electrons, Molecules and Bytes"

Enabling a Transition: Integrating Cleaner Energy

Transmission

Courtesy of AEP

Flexible Resources

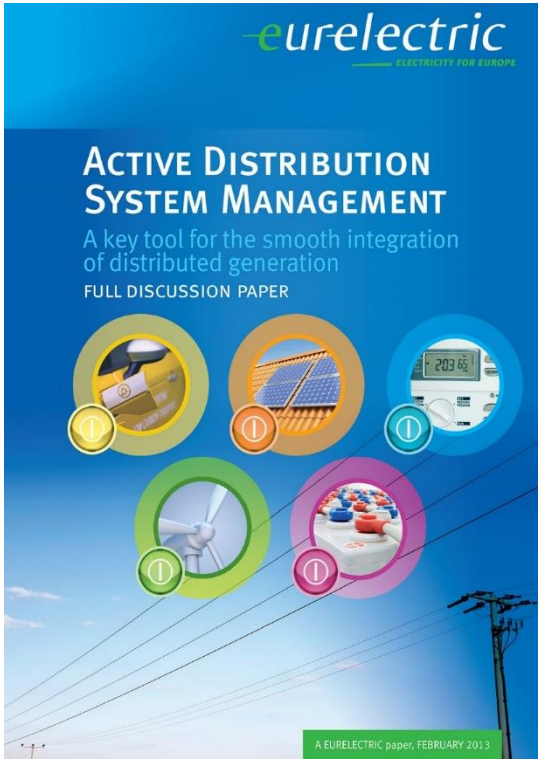


Courtesy of GE

Courtesy of Chevron

Courtesy of Ecobee

Smart Distribution



Courtesy of Eurelectric

Integrating Energy Resources

Providing *Cost Effective* Choice and Control with Increased Convenience and Comfort

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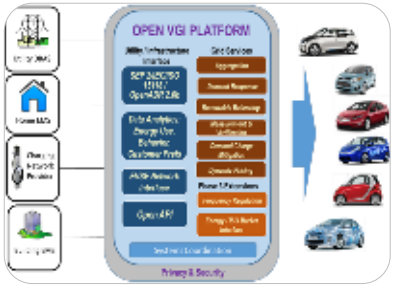
Integrated Electric Grid:
Enables Electricity and Transportation Interface



- **National Charging Infrastructure Deployment**
  - >$1B US of utility-owned/operated infrastructure
  - Utility web portal data access and analytics, billing interface
- **Electricity Grid-to-Vehicle Interface**
  - Time-of-Use rates and Demand Response signals
  - EV batteries: grid optimization
- **High Power Fast Charging Infrastructure**
  - 150 kW / 350 kW leads to ~1.5 MW / 3.5 MW per “gas station”

Value of the Grid: Electricity to Cleaner Transportation

Increasing Interface: Electricity, Gas and Water Infrastructure

- **Natural Gas and Electricity**
  - Pipeline and gas compression/electric generation station
  - Electric/gas markets
  - Power to gas (H_2) and gas to power (fuel cell)
- **Water and Electricity and Energy**
  - Water for electricity and electricity for water transportation
  - Electricity for water treatment, e.g., desalination
  - Electrotechnology for reducing water use, e.g., microwave drying

Value of the Grid: Electricity to Cleaner Gas and Integrated Water Infrastructure

Integrated Grid Enables Local Energy Grid

Heating
- Combined Heat and Power
- Teleheating
- Heat Pump

Efficient and Connected Buildings
- Building Automation Systems
- Smart Lighting
- Smart Appliances
- HVAC
- EV Charging Stations
- Smart Water Use

Connected Appliances

Energy Use & Production
- Grid supplied electricity/steam/gas
- Local Network to produce electricity/steam/gas

Storage
- Battery
- Power Conditioning
- Building Envelopes
- Water Heating

Thermal Storage

Increasingly Clean "Energy" will be Produced and Used Locally

Vision of a Low Carbon Future

- Consumers Driving Change
- Integration of All Energy Sources
- Enabled by the Integrated Electric Grid and Common Communication Protocols
- Electrification Enables Other Economy Sectors to Decarbonize

Together…Shaping the Future of Electricity