MICROGRID

THE SOLUTION TO OPTIMIZE THE POWER GENERATION MIX

IDEA 2016 – 107TH ANNUAL CONFERENCE

ST. PAUL, MN

JUNE 21, 2016

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A CULTURE OF CUSTOMER CARE

Solar Turbines
A Caterpillar Company

SOLAR TURBINES INCORPORATED

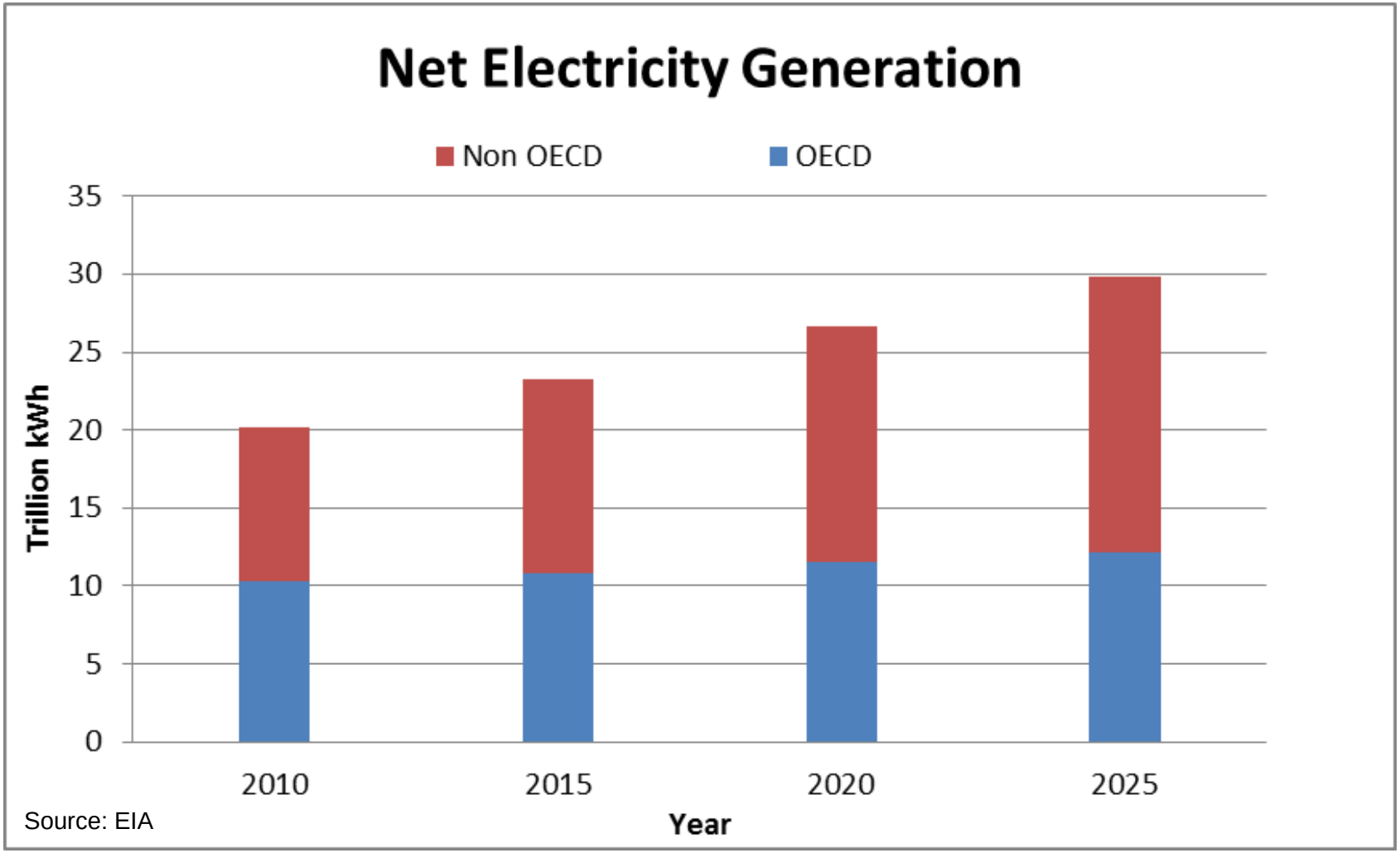
- World's Largest Manufacturer of Industrial Gas Turbines (1 to 22 MW)
- Over 15,000 Gas Turbines Sold
- Over 6,000 Gas Compressors Sold
- Installations in over 100 Countries
- Direct End-to-End Sales & Service
- More than 2 Billion Fleet Operating Hours
- Global Workforce ~ 8,000 Employees
- 48 Sales & Service Locations
- 70% of Products are Exported
- Based in San Diego, California, U.S.A.
- Subsidiary of Caterpillar Inc. Since 1981

AGENDA

- Current State of Electricity Production
- Challenge of Renewable Energy
- Microgrid – Definition
- Selection of the best technology
- Fossil fuel electric power generation
- Existing Microgrid – UCSD
- Summary

MACRO MARKET CONDITIONS

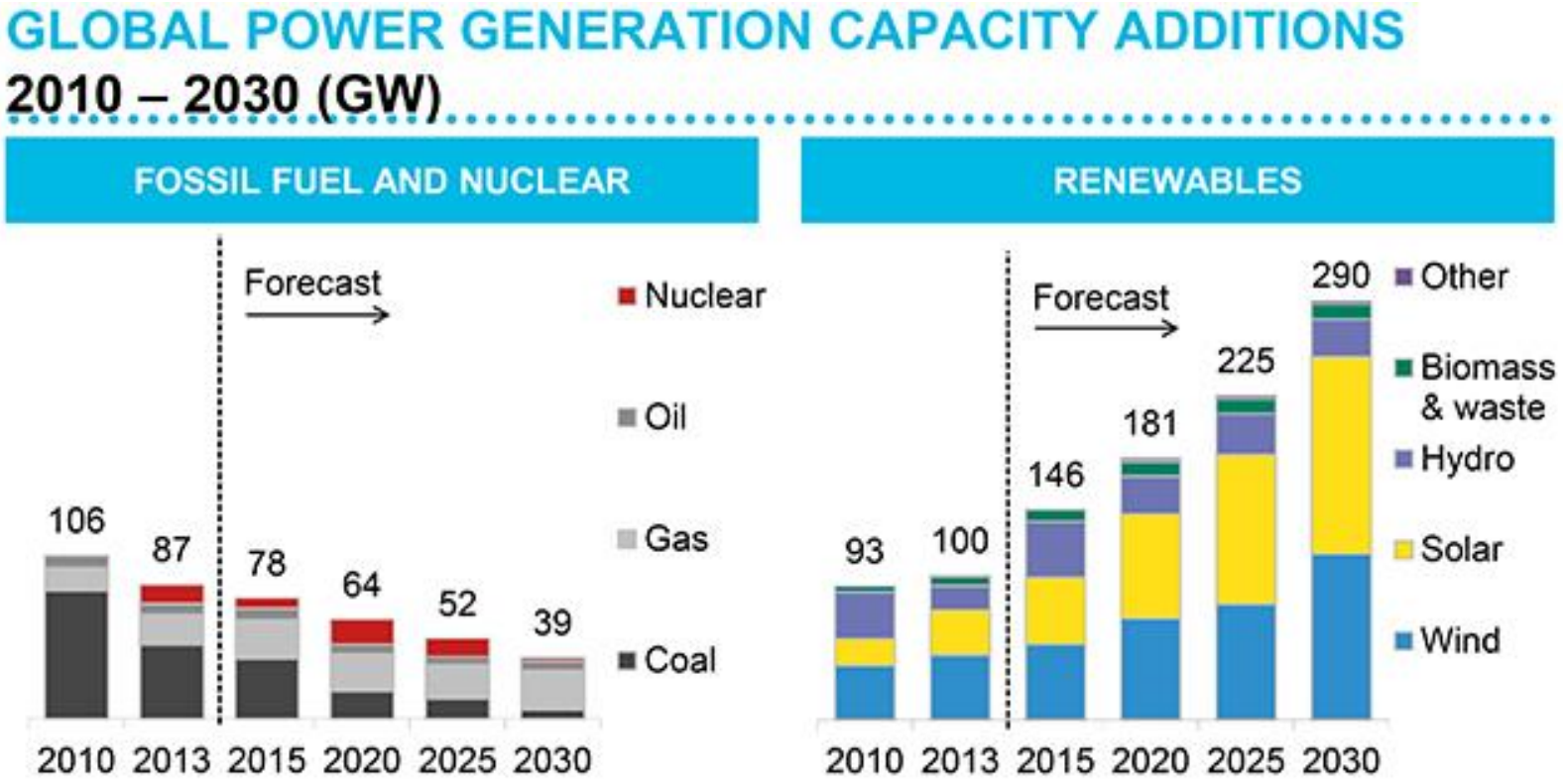
WW electricity generation is 2.2 %
OECD is 1.1 %
Non-OECD is 3.1 %



Source: EIA

MACRO MARKET CONDITIONS

Renewables is 2.8 %
Natural Gas is 2.5 %
Coal is 1.8 %
Liquid is -1.0 %



Source: Michael Liebreich/BNEFSummit 2014

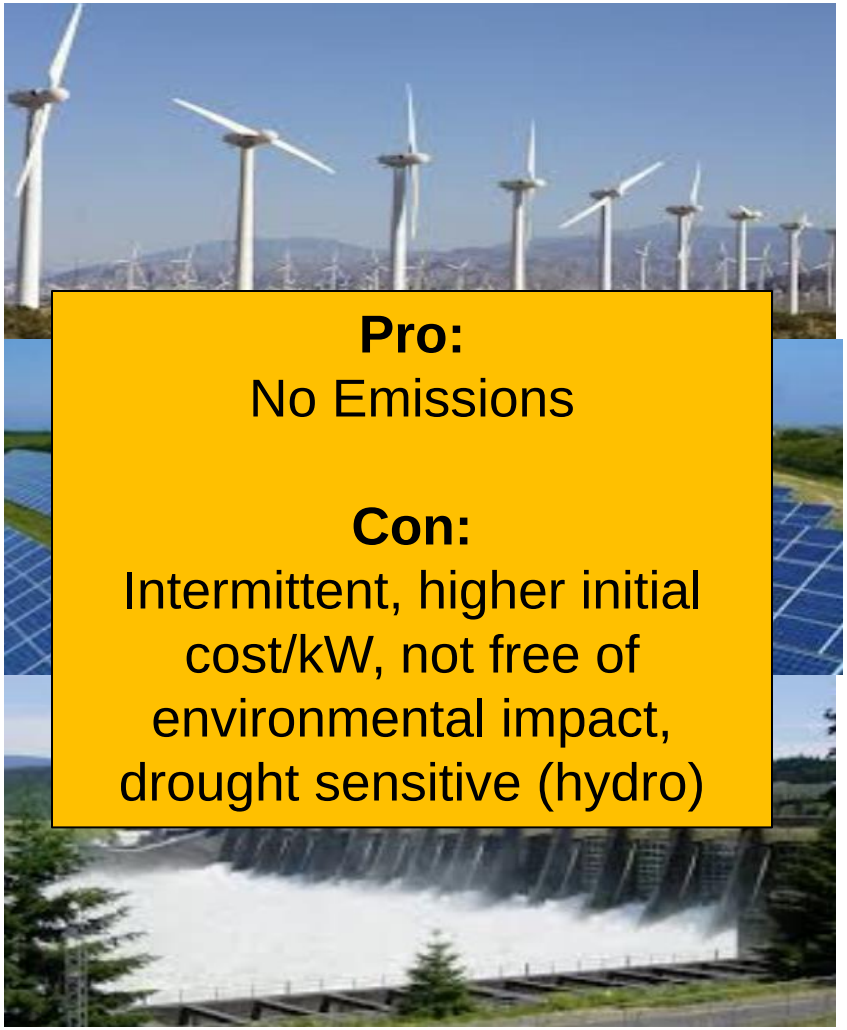
CURRENT POWER GENERATION

Conventional Power Generation

Pro:
Reliable Power Supply

Con:
Environmental Impact

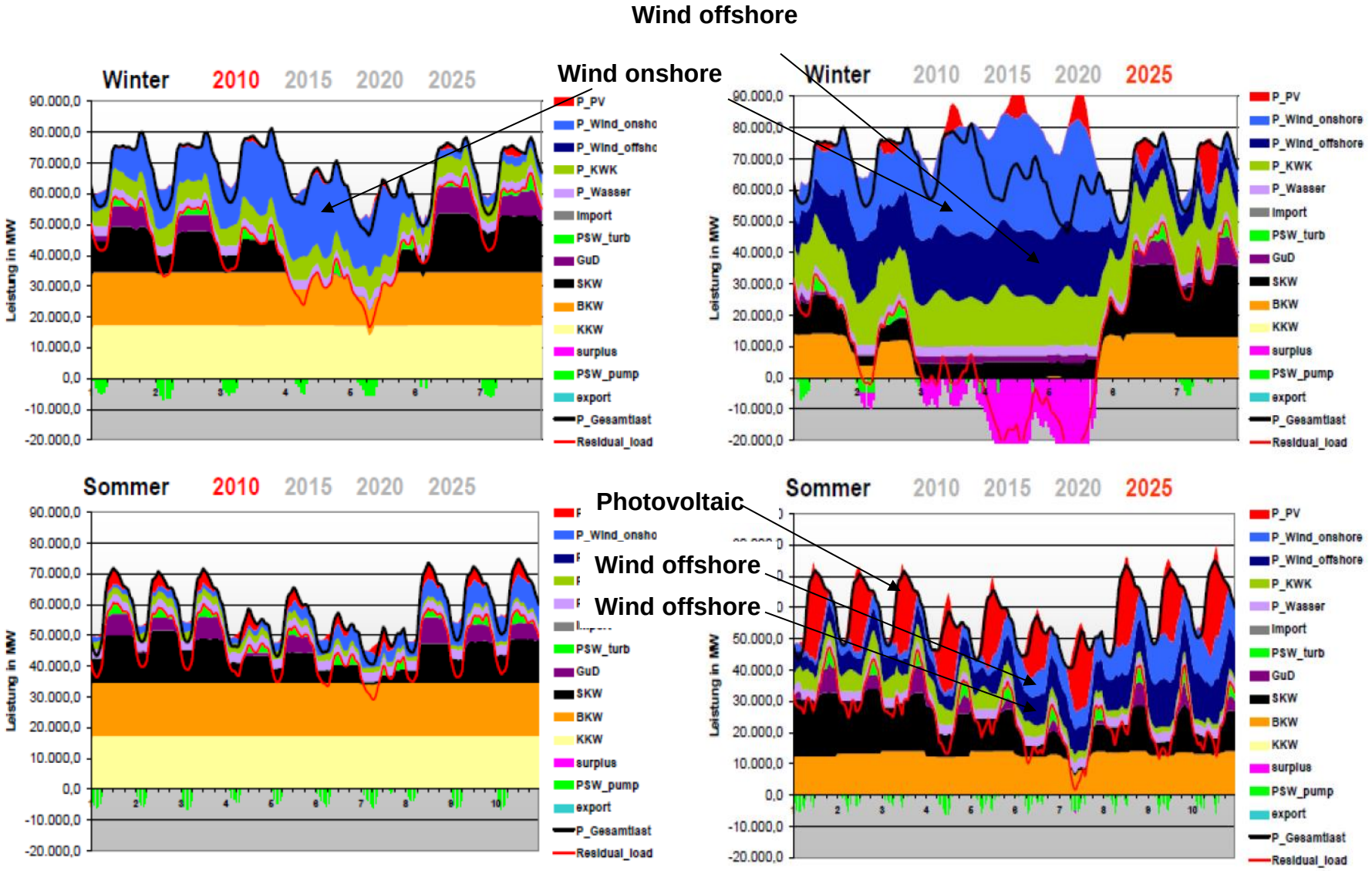
Renewable Power Generation



Pro:
No Emissions

Con:
Intermittent, higher initial cost/kW, not free of environmental impact, drought sensitive (hydro)

IMPACT OF RENEWABLES ON CONVENTIONAL EP



Source: University Rostock

TRANSMISSION / DISTRIBUTION

- Current Transmission System operates at capacity limits
- RE Wind and Solar plants are not close to consumer
- New transmission lines are required
- Cost intensive – installation / O&M
- Long and complicated approval process
- Transmission losses
  - World average: 8 %
  - USA: 6 %
  - Germany: 3.9 %

NATURAL DISASTERS

- If hit by Natural Disaster – Damage to Centralized Electric Power Supply could cause widespread black-outs

- **Biggest Event in 2012:**

- **Hurricane Sandy:**
  - Caused damages from Island Jamaica through New England
  - 2nd costliest US hurricane since 1900
  - 8.5 Mill People were without power for months
  - $70 billion in damage

INTERIM SUMMARY

- ✓ More and More RE being added to the system
- ✓ Adding RE doesn’t guarantee stable power
- ✓ Major RE sources are Wind and Solar – intermittent power supply
- ✓ Right power mix is necessary – ensure stable power w/o price increase
- ✓ New Transmission lines needed
- ✓ Current Transmission / Distribution losses in USA is around 6 %
- ✓ Grid disruption due to equipment failure / natural disasters or cyber attacks can compromise broad populations or sensitive facilities

MICROGRID - DEFINITION

US DoE definition:

- Group of interconnected loads and distributed energy resources
- Act as a single, controllable entity to the grid
- Can operate grid-connected or island mode

Benefits of Mircogrids:

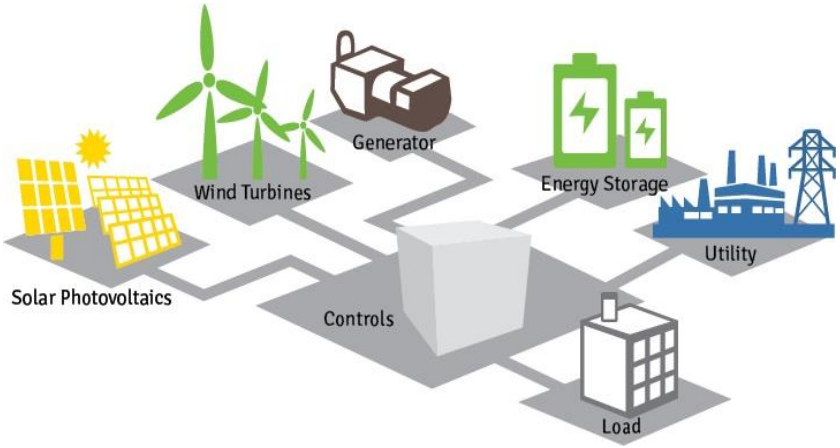
- Grid Resiliency
- Reliability
- Security
- Optimized use of fossil and renewable energy
  - Reduced Cost of Power
  - Reduced Emissions
- Reduced Distribution losses

CORE COMPONENTS OF A MICROGRID

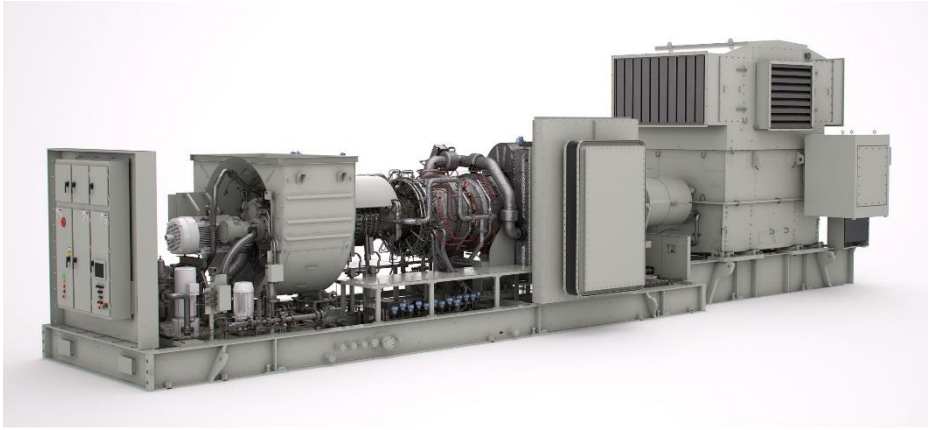
Typical Power Generation Components are:

- ***Renewable Sources:***
  - Solar panels
  - Wind turbines
  - Small Hydro plants
  - Geothermal plants

  } Intermittent Power

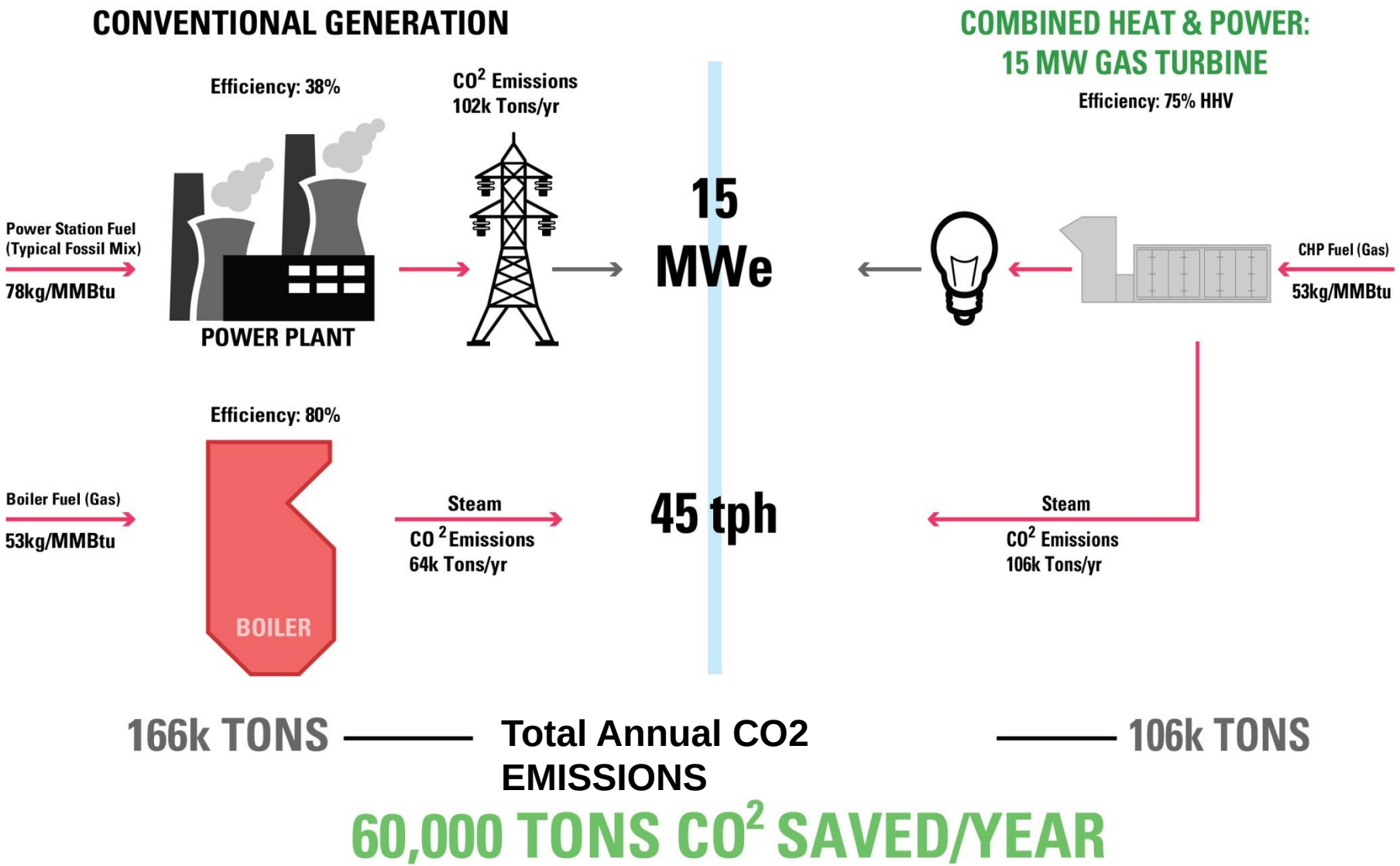


- ***Conventional Sources:***
  - Fossil fuel fired plants – Turbines or Recips - Gas or Liquid fuel



  - Operating in Simple Cycle or Combined Heat and Power (CHP)

CO2 EMISSIONS REDUCTIONS FROM CHP



MICROGRIDS – CURRENT STATE

- Currently 1,250 MW of microgrid capacity in US
- 80% is centered in 7 States (NY, GA, TX, CA, MD, OK, AK)
- Up to date microgrids serve:
  - army bases
  - remote communities
  - Campuses (UCSD, UC Irvine, Princeton University)
- Utilities are slowly catching up - investor owned will play a larger role than public power utilities (less approval required)
- Clear rules/regulations still pending from states and regulatory agencies
- Microgrids are an innovation to an ageing utility gird

UC SAN DIEGO (UCSD) - 42 MW MICROGRID

Campus Quick Facts

With a daily population of over 45,000, UC San Diego is the size and complexity of a small city.

As a research and medical institution, we have **TWO** times the energy density of commercial buildings

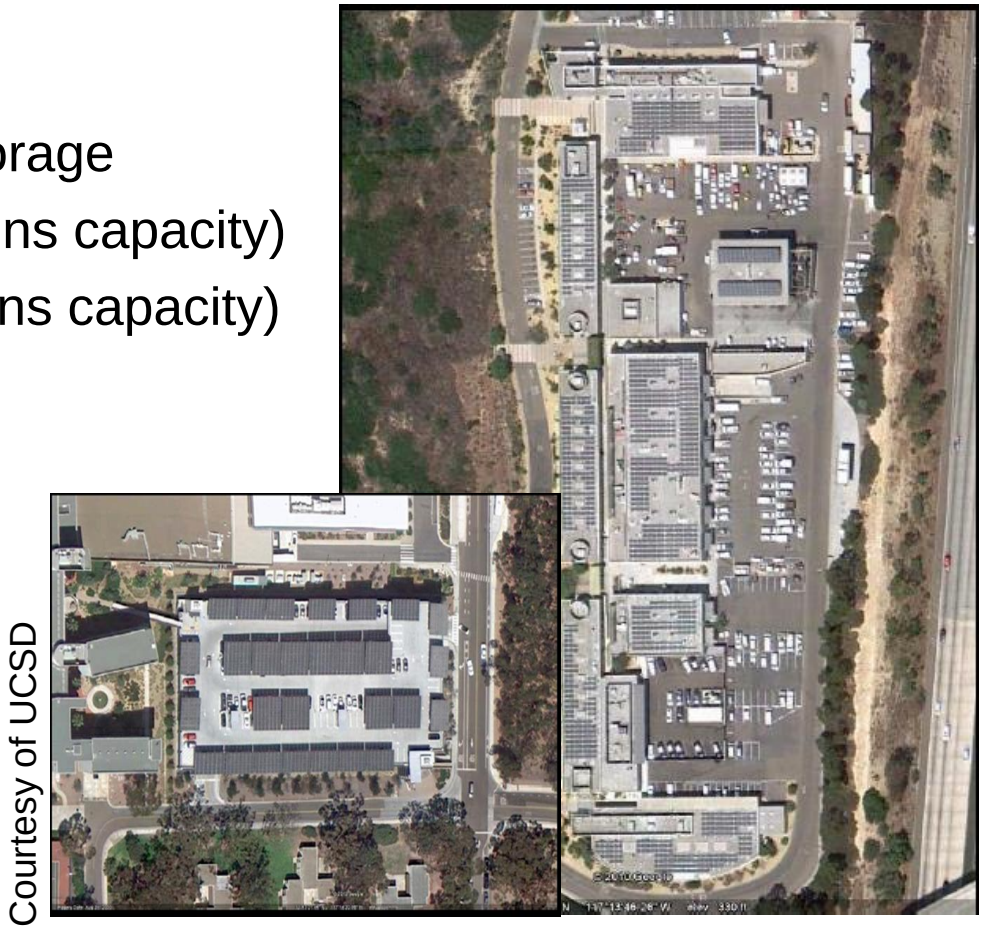
12 million sq. ft. of buildings, $200M/yr of building growth
9 million gallons per day water/sewage
100 buildings
25 buildings are critical (load shedding)

Awarded 1 of 3 “Energy Star Awards” by EPA in 2010

Courtesy of UCSD

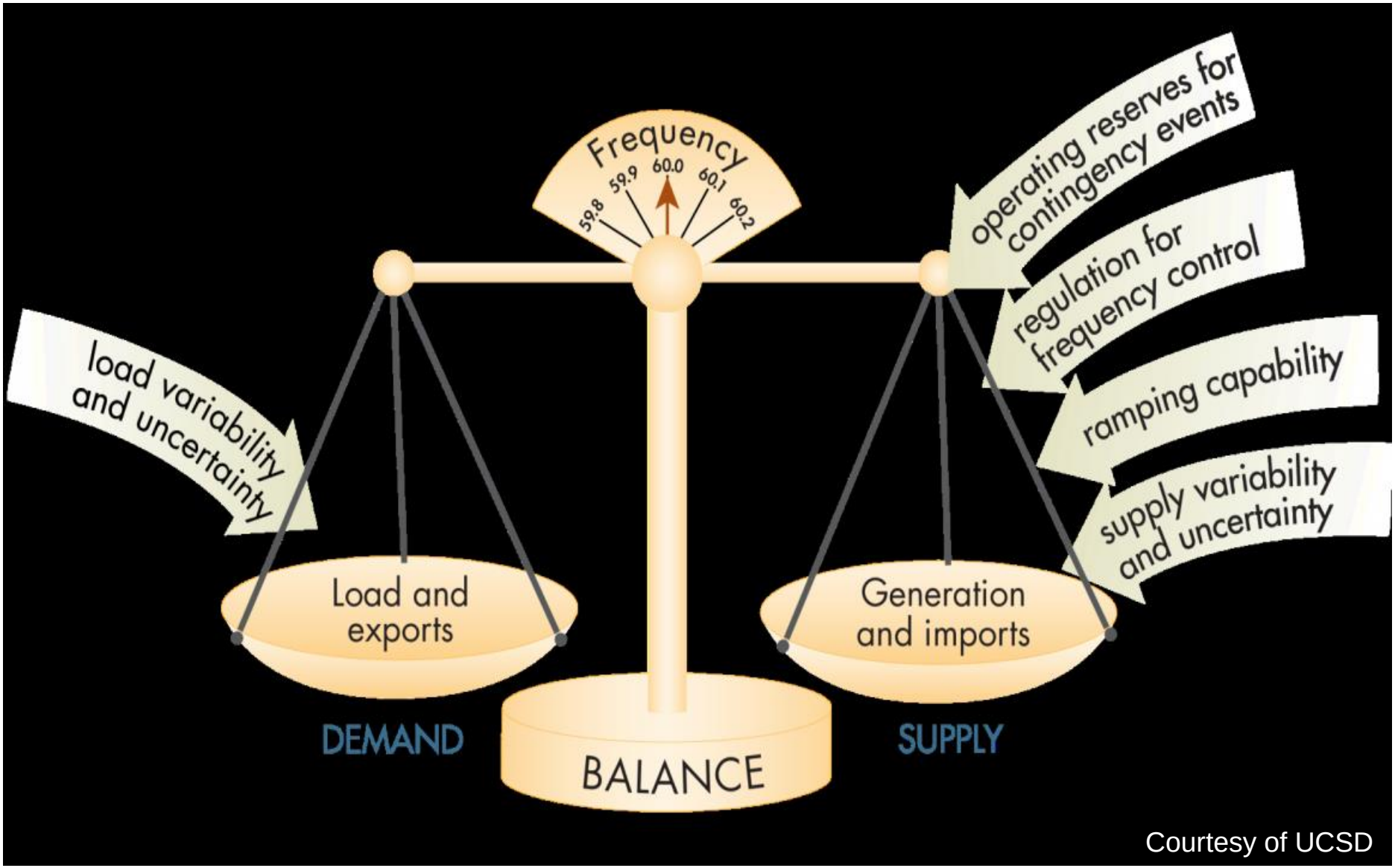
UCSD MICROGRID

- Self Generation >85 % electricity, 95% heat and cooling (annual)
- 30 MW CHP plant comprising of 2 x Solar T130 Gas turbines operating on natural gas with heat recovery
- 3 MW steam turbine
- 3.8 million gallons chilled water storage
- 3 steam driven chillers (~10,000 tons capacity)
- 8 electric driven chillers (~7,800 tons capacity)
- 3.0 MW natural gas fired fuel cell
- 2.7 MW of Photovoltaics
- 3.0 MW/6 MWH energy storage
- 75 emergency backup generators



Courtesy of UCSD

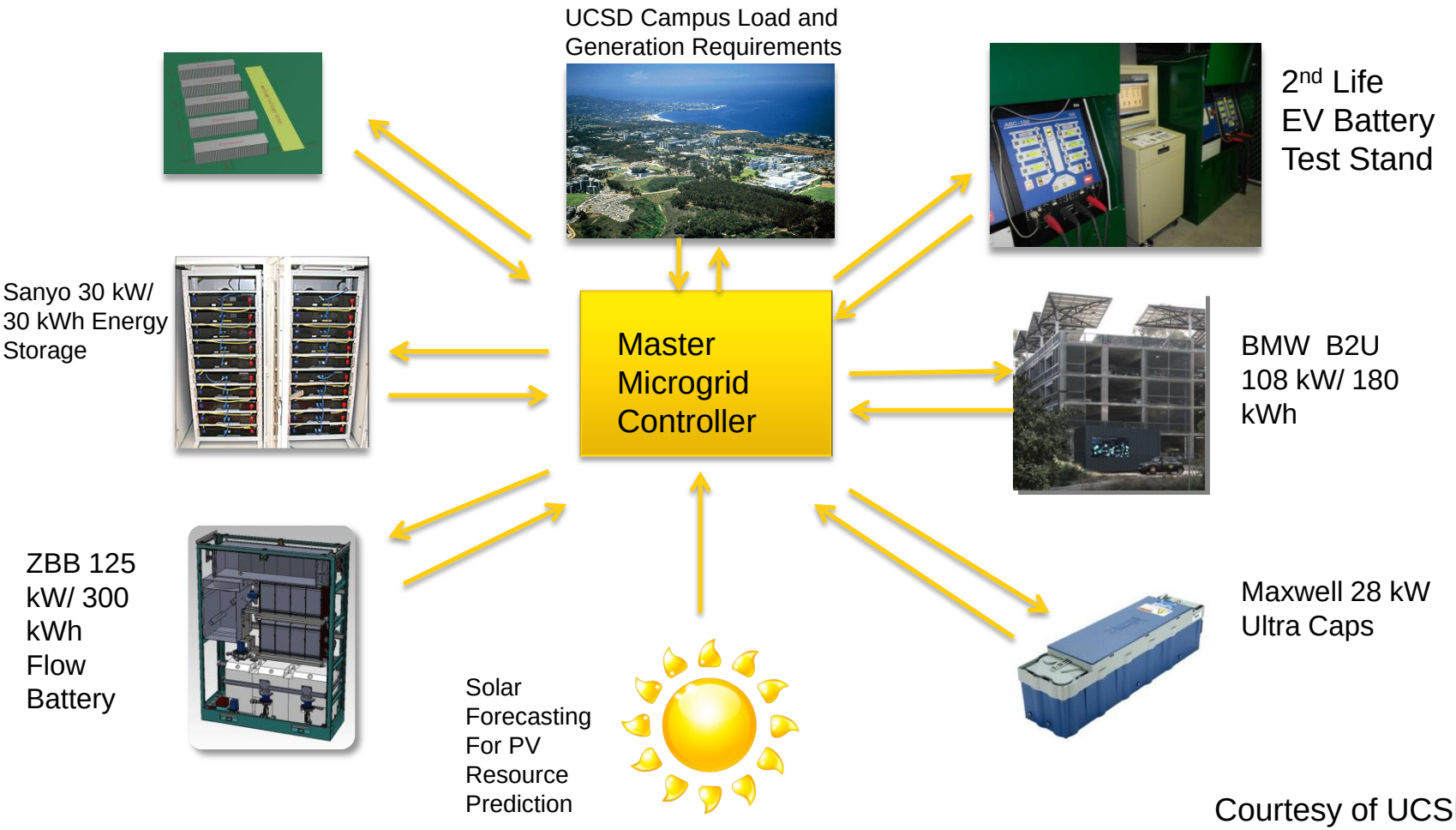
MICROGRID - SUPPLY = DEMAND



Courtesy of UCSD

UCSD MICROGRID

Coordinated Control and Dispatch of Distributed Energy Resources To Maximize System Efficiency



Courtesy of UCSD

UCSD MICROGRID

The Central Utility Plant Saves the UCSD Campus

- US$ 800,000 per month
- 40% reduction in CO Emissions

THE IMPORTANCE OF MICORGRIDS

Improved Reliability

- Self-sustaining islanding capability reduces chance of cascading system failure
- Overall system less vulnerable to massive system wide events (i.e. Superstorm Sandy)
- Enhances larger grid operation by balancing load and generation on a localized level
- Resolves renewable generation variability on a local level

Enhances Integration of Renewable Generation

- Supports implementation of CHP with renewable generation on a localized level
- Reduce carbon footprint by maximizing efficiency of energy production and consumption on a local level
- Encourages third party investment in the local grid
- Reduces system losses by locating generating sources near customer loads

CONCLUSIONS AND KEY POINTS

- Microgrids do improve grid resiliency and reliability
- Microgrids result in improved operational efficiencies and reduced costs
- Microgrids can reduce carbon foot print when CHP is applied
- CHP can function as the “Heart” of the Microgrid
- Energy Storage is a key component to enable high penetration of renewables in a Microgrid
- Early planning and design of a Microgrid is important
- Market and Regulatory reform is required to realize full benefits of Microgrids

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