Combined Heat and Power (CHP) and the Microgrid

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May 2, 2017

U.S. Department of Energy
CHP Technical Assistance Partnerships
SOUTHWEST

INTERNATIONAL DISTRICT ENERGY ASSOCIATION

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Speakers

- Gavin Dillingham, PhD, Director of SW CHP TAP
- Carlos Gamarra, P.E., CEM, SW CHP TAP
- Moderator - Laxmi Rao,
  Director, International District Energy Association

CHP Technical Assistance Partnerships

- **Education and Outreach**

  Providing information on the energy and non-energy benefits and applications of CHP to state and local policy makers, regulators, end users, trade associations, and others.

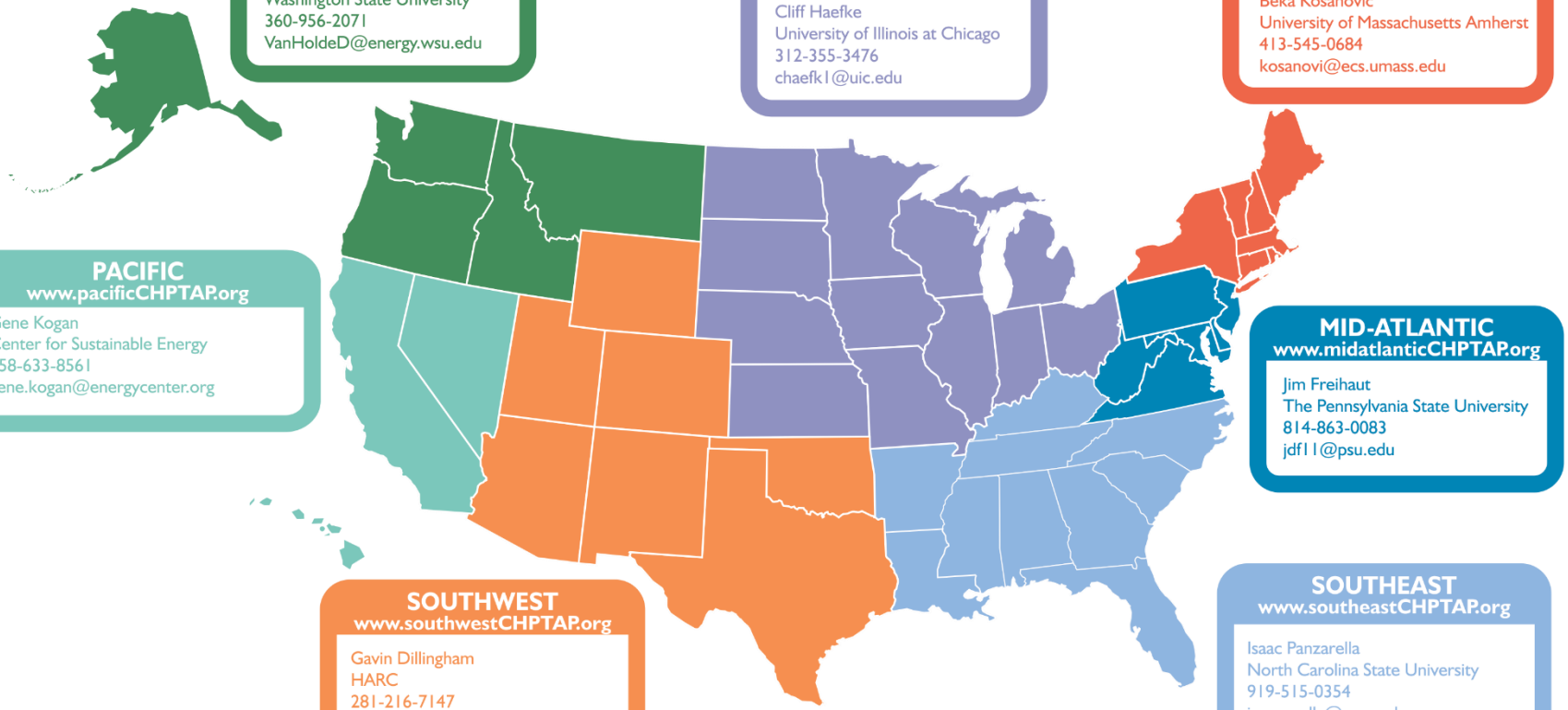
- **Technical Assistance**

  Providing technical assistance to end-users and stakeholders to help them consider CHP, waste heat to power, and/or district energy with CHP in their facility and to help them through the development process from initial CHP screening to installation.

- **Market Opportunity Analysis**

  Supporting analyses of CHP market opportunities in diverse markets including industrial, federal, institutional, and commercial sectors

DOE CHP Technical Assistance Partnerships (CHP TAPs)



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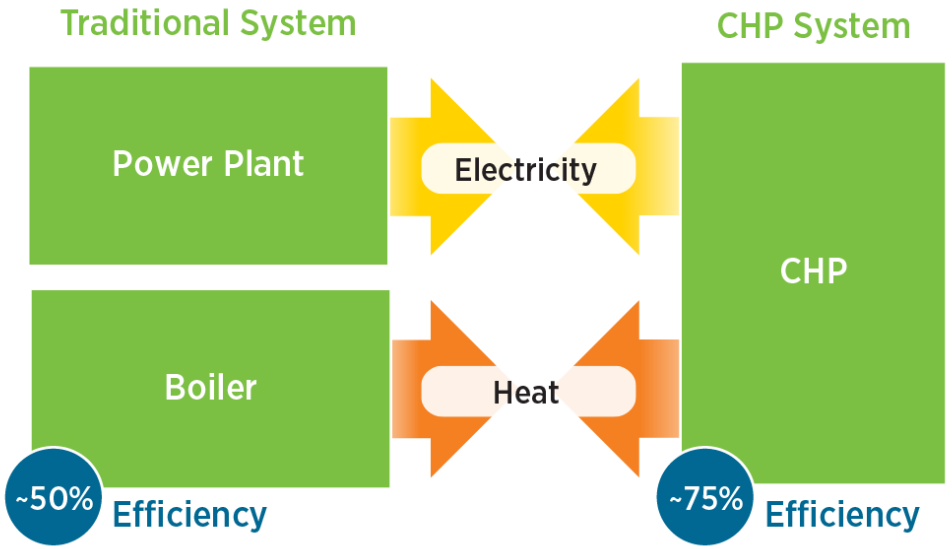
Outline

- **CHP for Microgrids**
- **Specific CHP and Resiliency Projects**
- **CHP Project Resources**
- **Q&A**

CHP Overview

CHP: The Foundation of a Microgrid

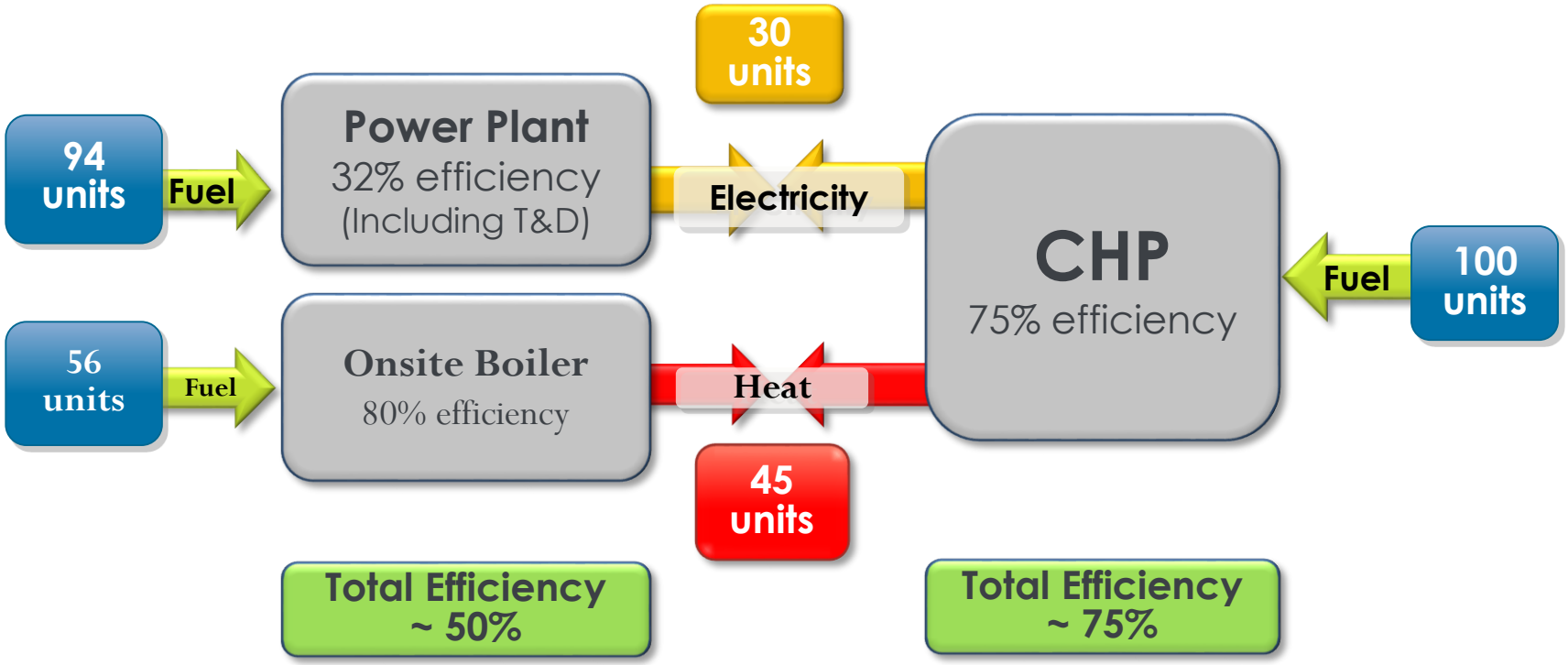
- Form of Distributed Generation (DG)
- An integrated system
- Located at or near a building / facility
- Provides at least a portion of the electrical load and
- Uses thermal energy for:
  - Space Heating / Cooling
  - Process Heating / Cooling
  - Dehumidification



CHP provides efficient, clean, reliable, affordable energy – today and for the future.

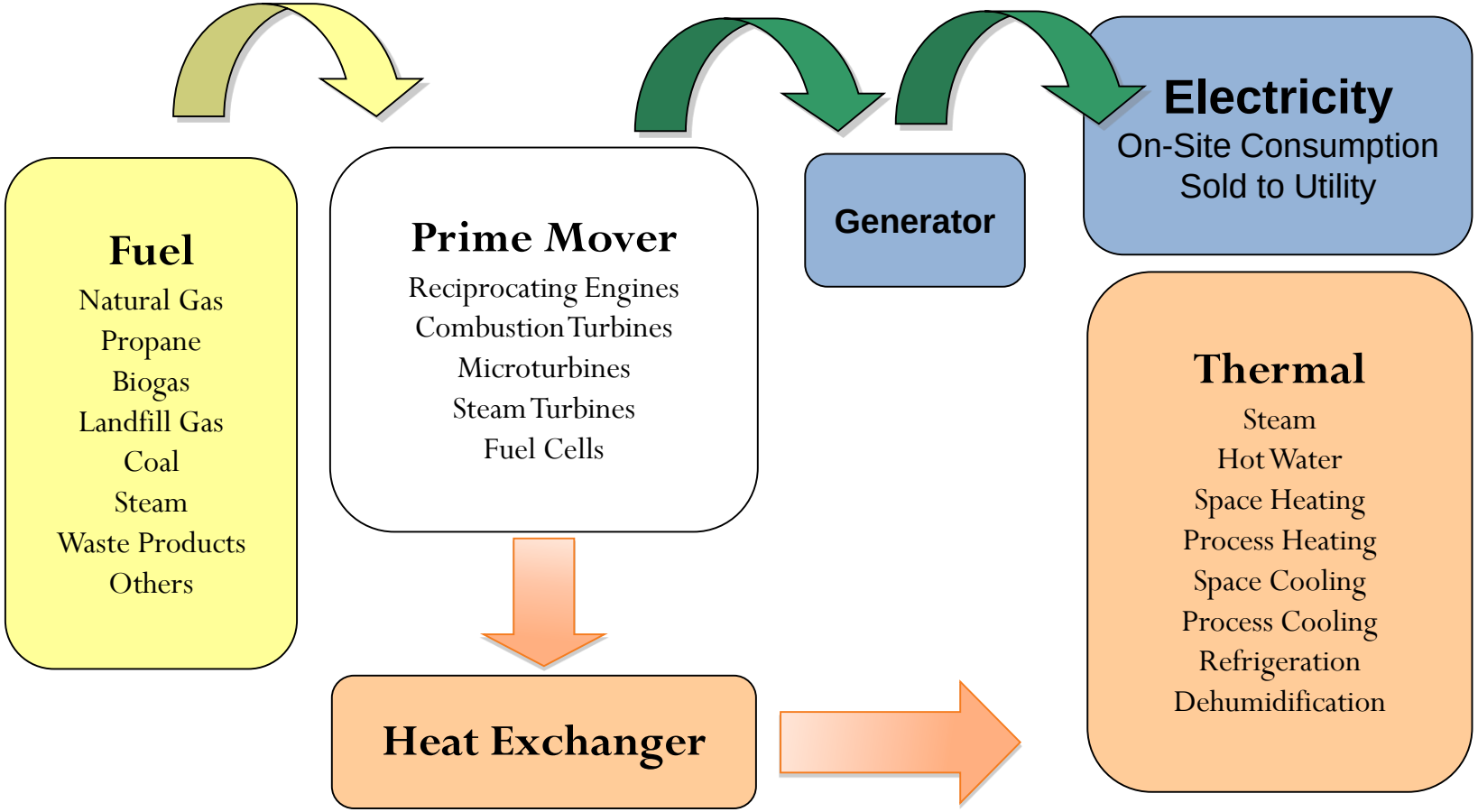
Source: http://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_clean_energy_solution.pdf

CHP Recaptures Heat of Generation, Increasing Energy Efficiency, and Reducing GHGs



30 to 55% less greenhouse gas emissions

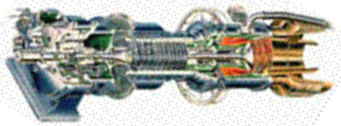
CHP System Schematic



Common CHP Technologies

Microturbines

Gas Turbines



Reciprocating Engines

Fuel Cells

50 kW | 100 kW | 1 MW | 10 MW | 20 MW

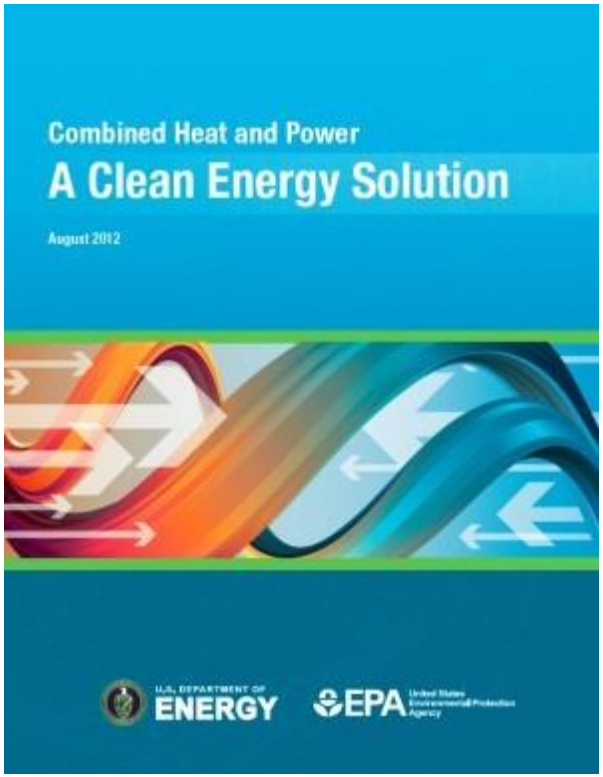
What Are the Benefits of CHP?

- CHP is **more efficient** than separate generation of electricity and heating/cooling
- Higher efficiency translates to **lower operating costs** (but requires capital investment)
- Higher efficiency **reduces emissions** of pollutants
- CHP can also increase **energy reliability** and enhance power quality

Emerging National Drivers for CHP

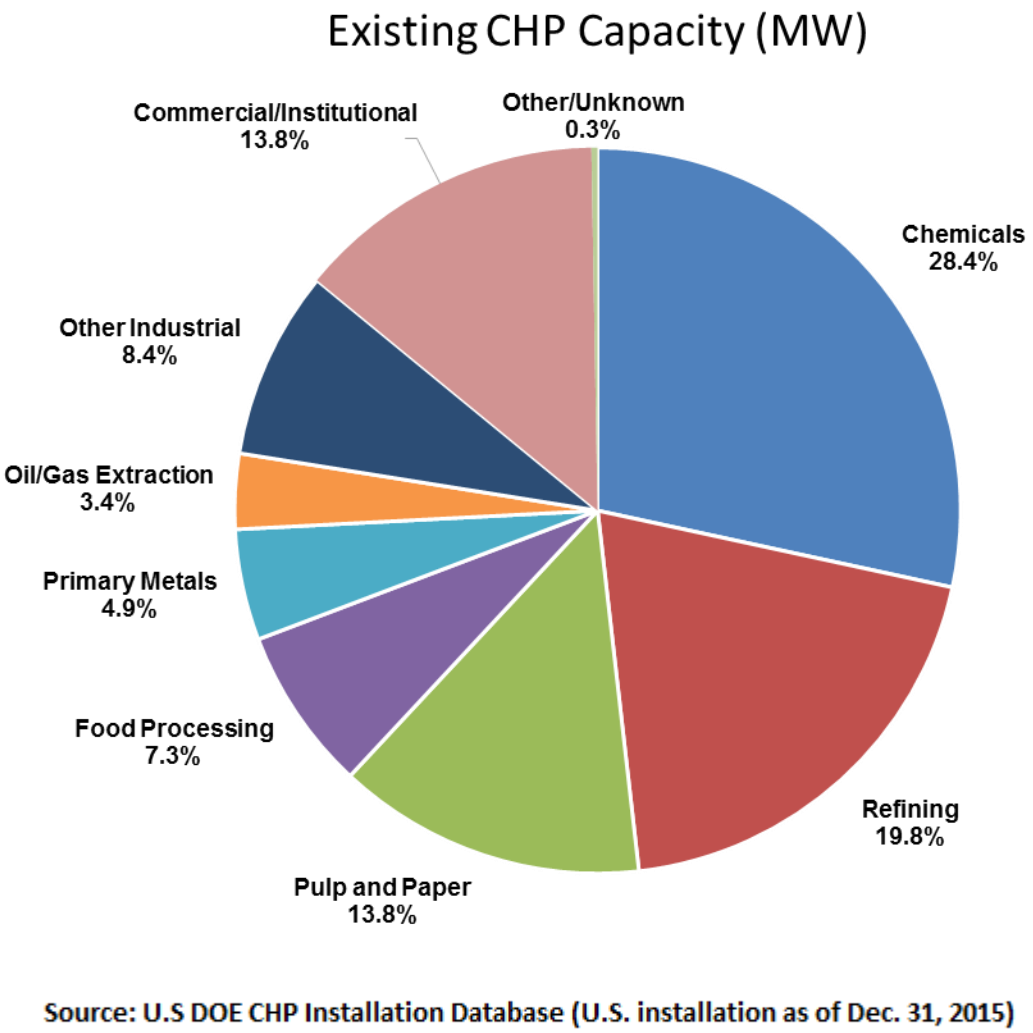
- Benefits of CHP recognized by policymakers
  - State Portfolio Standards (RPS, EEPS), Tax Incentives, Grants, standby rates, etc.
- Favorable outlook for natural gas supply and price in North America
- Opportunities created by environmental drivers
- Utilities finding economic value
- Energy resiliency and critical infrastructure

DOE / EPA CHP Report (8/2012)



http://www1.eere.energy.gov/manufacturing/distributedenergy/pdfs/chp_clean_energy_solution.pdf

CHP Today in the United States



Source: U.S DOE CHP Installation Database (U.S. installation as of Dec. 31, 2015)

- **81 GW** of installed CHP at over 4,300 industrial and commercial facilities
- 8% of U.S. Electric Generating Capacity; 14% of Manufacturing
- Avoids more than **1.8 quadrillion Btus** of fuel consumption annually
- Avoids **241 million metric tons of CO_2** compared to separate production

Finding the Best Candidates:
Some or All of These Characteristics

- High and constant thermal load
- Favorable spark spread
- Need for high reliability
- Concern over future electricity prices
- Interest in reducing environmental impact
- Existing central plant
- Planned facility expansion or new construction; or equipment replacement within the next 3-5 years

CHP and Microgrids

Definitions – Microgrid

CERTS (2002) *White Paper on integration of Distributed Energy Resources. The CERTS MicroGrid Concept*

IEEE 1547.4 -2011 *Guide for Design, Operation, and Integration of DR Island Systems with EPSs*

A local power system (a power system on its own)

- ✓ Locally/Regionally limited energy system (no actual size limitations).
- ✓ It is an intentionally planned entity, focused on electrical demand covering.
- ✓ Includes energy generation, energy consumption systems, and (sometimes) energy storage devices.
- ✓ A multi-site microgrid may require developing a power distribution network.
- ✓ It may also produce thermal energy (cold and/or, heat).

Can operate in interconnected or/and isolated states.

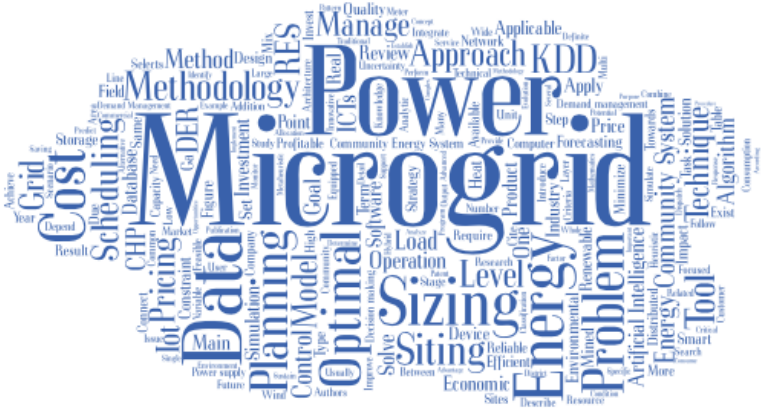
- ✓ Has its own control and management systems
- ✓ Control relies on power electronic devices and ICTs.
- ✓ Could work in coordination with other grids, even be operated as a unit of a larger grid.
- ✓ Can operate different distributed energy resources at a time.

Can take part of a Smart grid or not, but it can be smart too. Scalability.

- ✓ Can develop DR and/or DSM strategies.

Why do we talk about microgrids now?

An existing concept updated by technological advances and market conditions.



1880s — *1970s Oil crisis* — *1990s* — *2???*

Local small generation plants, manually operated, using local energy resources.

POWER SYSTEMS CENTRALIZATION

Big power plants and long transmission lines remotely operated.

POWER SYSTEMS DECENTRALIZATION

The role of microgrids in the future power grid

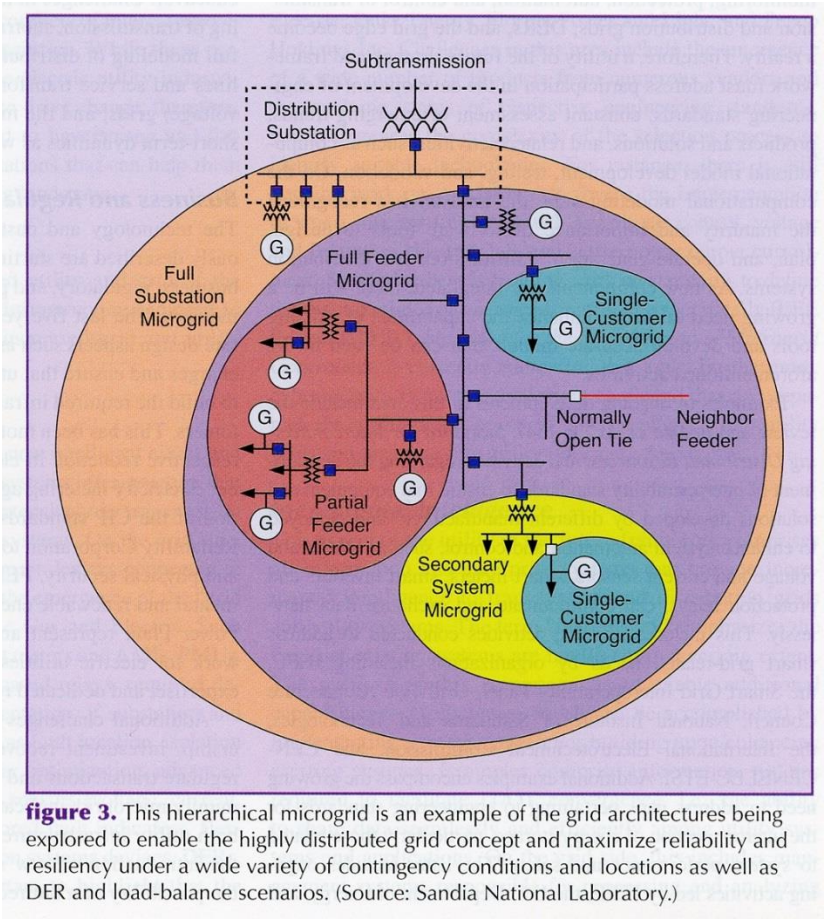
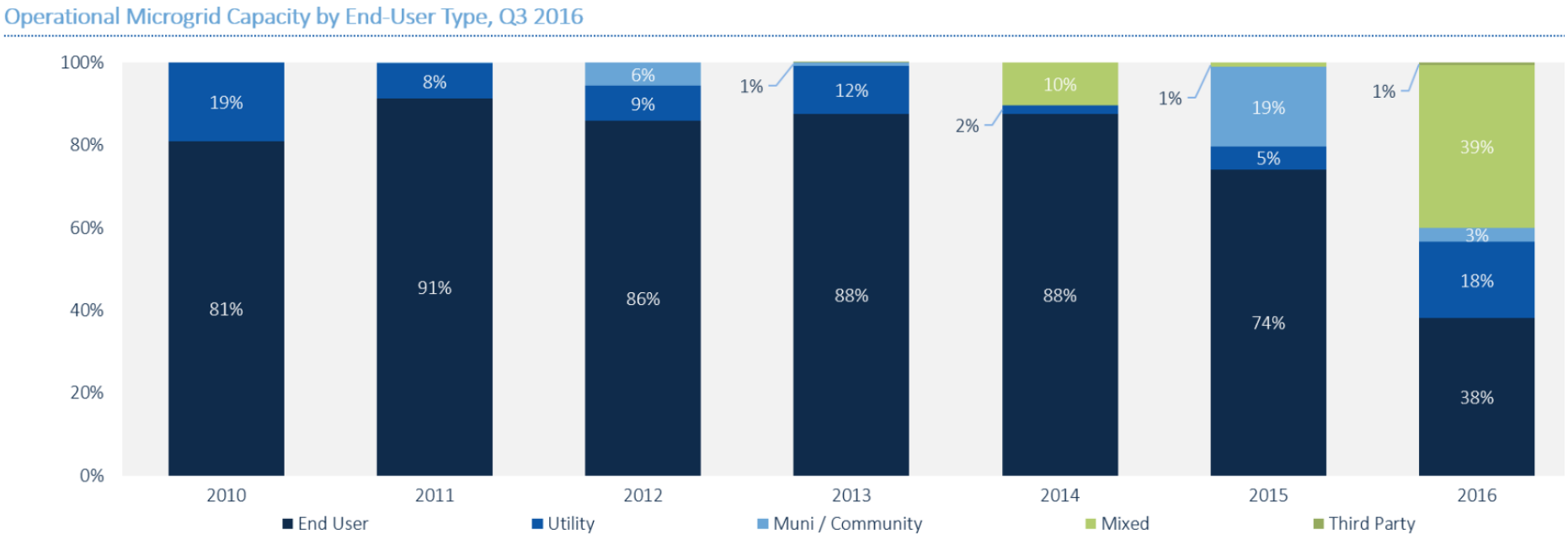


figure 3. This hierarchical microgrid is an example of the grid architectures being explored to enable the highly distributed grid concept and maximize reliability and resiliency under a wide variety of contingency conditions and locations as well as DER and load-balance scenarios. (Source: Sandia National Laboratory.)

SOURCE: *IEEE POWER & ENERGY. Vol.*14, Number 5, September/October 2016

- Provide power and/or ancillary services.
- Act as individual power systems, take part of other microgrids or act a as part of the distribution grid.
- No massive establishment: only those based on competitive advantages or added value proposals.
- Regarding the other power systems they can:
  - Coexist: as individual power systems
  - Cooperate: take part of other microgrids or work as part of the distribution grid
  - Compete: as individual power systems

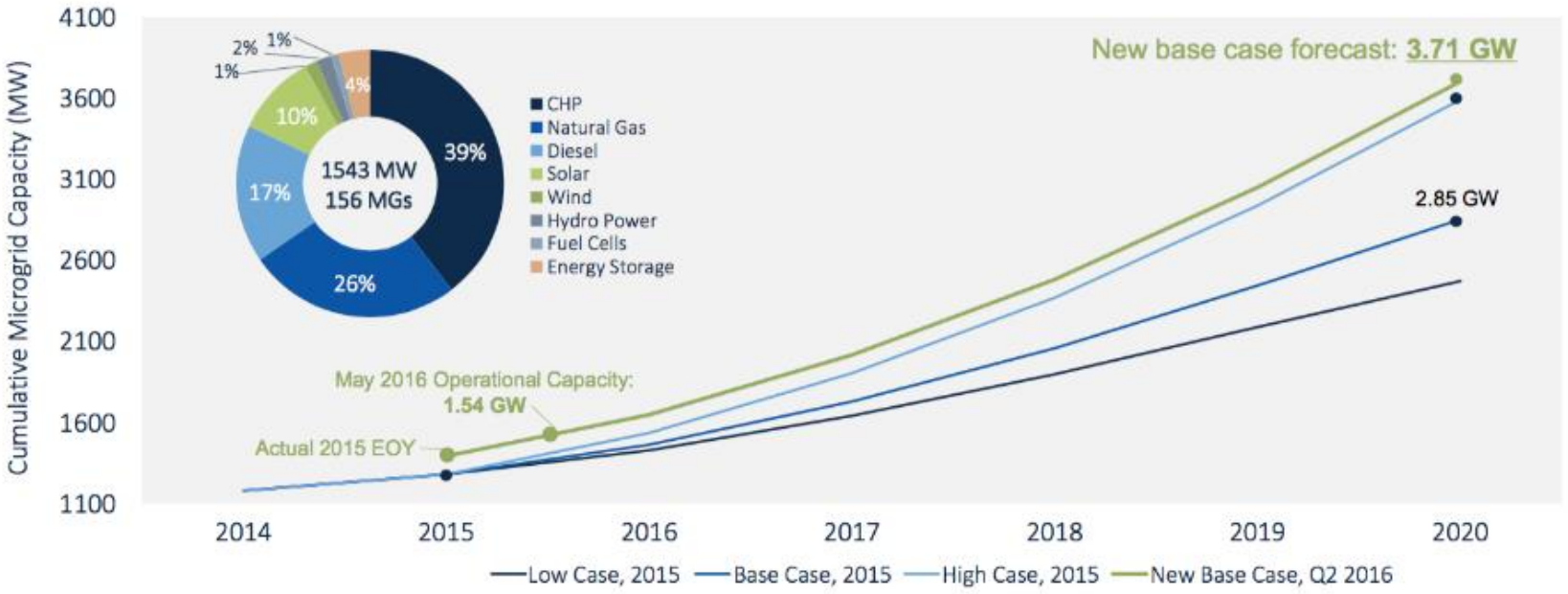
MG market evolution



SOURCES: www.greentechmedia.com/articles/read/US-Installed-Microgrid-Capacity-to-Grow-115-And-Reach-4.3-GW-Over-Next-Fiv

MG market evolution

- Market research companies are updating their forecasts.
- The MG market is expected to reach 3.71 GW of operational capacity in 2020.
- **A 39% of the existing microgrids are based on CHP systems.**



SOURCES: www.greentechmedia.com/articles/read/u.s.-microgrid-growth-beats-analyst-estimates-revised-2020-capacity-project

CHP, District Energy & Microgrids: Combined Benefits

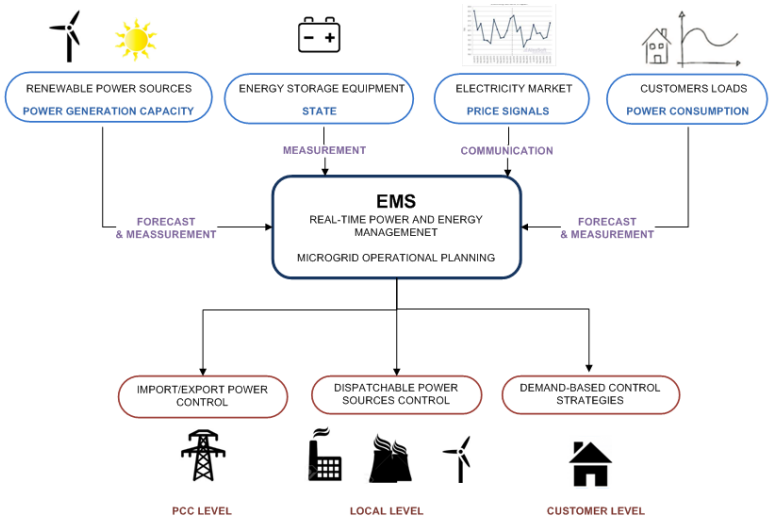
CHP technologies provide competitive advantages to microgrids

- CHP provides reliable dispatchable power
- CHP provides thermal energy during grid outage
- CHP results in daily operating cost savings that can significantly help offset costs of resilient microgrids
- CHP can offset some capital costs associated with investments in traditional backup power

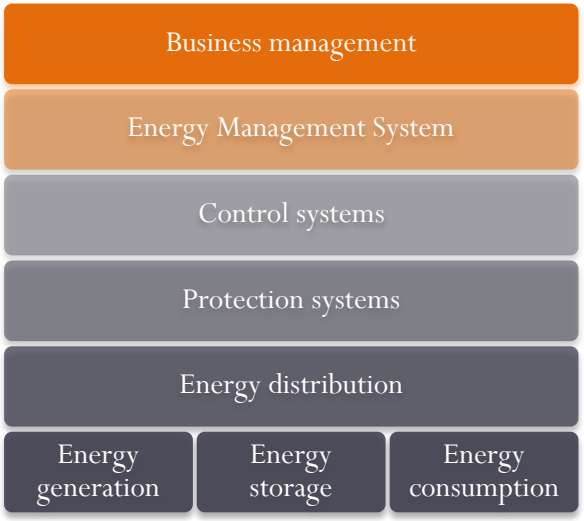
What can a CHP-based MG do for you or your company?

• To produce electricity, cold and/or heat at a time	**Cost efficiency , Reliability and Sustainability**
• To take advantage of local fuels or sources of energy	**Cost efficiency , Reliability and Sustainability**
• To improve the energy efficiency of your facilities	**Cost efficiency , Reliability and Sustainability**
• To reduce the impact of tariffs or electricity price oscillations	**Resiliency**
• To protect/guarantee the supply against external contingencies	**Security, Resiliency, Reliability**
• To include distributed generation based on clean technologies	**Sustainability**
• To minimize transmission and distribution losses	**Sustainability**
• To generate collective economic returns	**Cost efficiency , Reliability and Sustainability**
• To be built or upgraded in several stages	**Scalability, and Cost efficiency**
• To supply energy where there is no power supply	**Technology and community development**
• To provide high-quality energy both connected or isolated from the main grid	**Reliability, Cost efficiency**
• To promote investments and create jobs	**Technology and community development**

Systems in a microgrid



SOURCE: A KNOWLEDGE DISCOVERY IN DATABASES APPROACH FOR INDUSTRIAL MICROGRID PLANNING. Gamarra, C.,Guerrero, J M.,Montero , E. Renewable & Sustainable Energy Reviews. 2016. (doi 10.1016/j.rser.2016.01.091)



>1 BUS
>1 USER
>1 OWNER
1 OPERATOR

1 BUS
1 USER
1 OWNER

1 BUS
>1 USER
1 OWNER

>1 BUS
1 USER
1 OWNER

>1 BUS
>1 USER
>1 OWNER

COMPLEXITY

U.S. DEPARTMENT OF ENERGY
CHP Technical Assistance Partnerships
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CHP-based Microgrid Projects

University of California San Diego Microgrid

- 27 MW Natural Gas Turbine CHP
- 2.8 MW Directed Biogas Fuel Cell
- Thermal Driven Cooling
- Chilled Water Storage
- Electric Storage Planned
- Backup Gensets & UPS

Houweling's Tomatoes

- 13 MW Natural Gas Engine CHP
- 2.3 MWs backup Gen sets
- 128 acres under glass
- 1 MW Solar PV
- 3 million gallons hot water storage

Houweling's Tomatoes

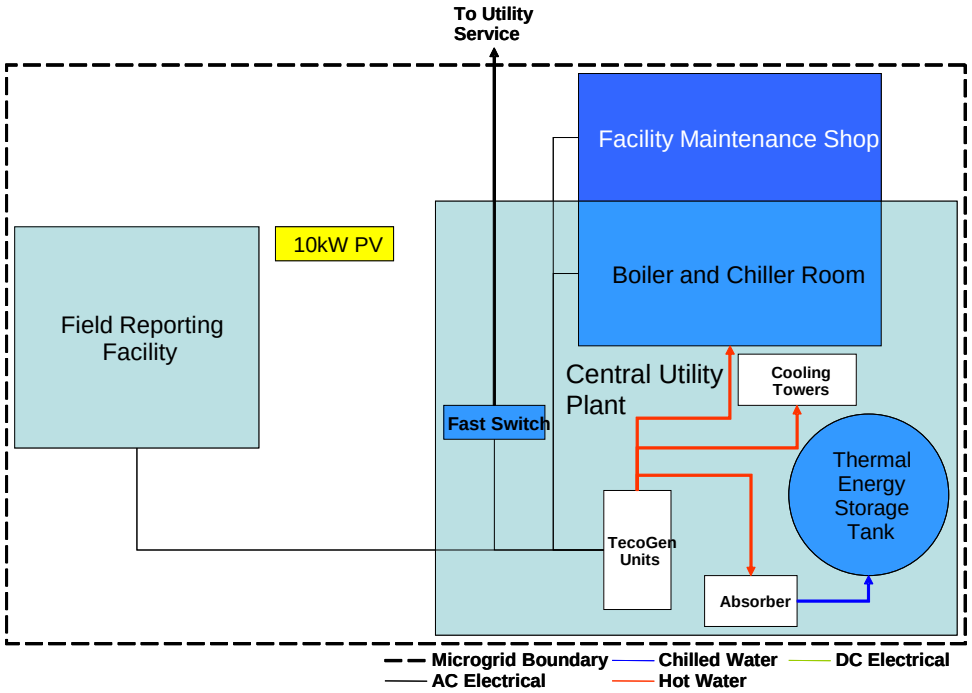
- During the Day
  - Electricity sold to SCE
  - Cooled exhaust sent to Greenhouse (GH)
  - Recovered heat stored in Thermal Energy Storage (TES) tanks
- During the Night
  - Electricity powers grow-lights isolated from grid
  - Hot water used to keep GH above 62°F
- PV & SCE provide power for non grow-light on-site loads (< 3 MW)
- CHP operating hours limited by thermal demand as there is no heat dump
- NOx and CO emissions near zero
- Electric Efficiency – 38% HHV; Overall Efficiency – 88% HHV
- 53% fewer GHG emissions than avoided grid emissions
- Hydroponic farming uses 85% less water than open field farming
  - Recycles unused crop water
  - Collects and stores rain water
  - Condenses and uses water in engine exhaust (9,500 gallons per day)
- Product yield as much as 25 times higher than open field farming

SMUD Microgrid at Corporate Central Utility Plant

- SMUD is a Sacramento's community-owned, not-for-profit electric service.
- Three 100 kW engine inverter based CHP units
- 10 kW solar PV
- 128 ton absorption chiller
- Chilled water storage
- Smart Switch

SMUD Microgrid

- Integrated Energy System
- Interconnected loads
- Distributed Energy Resources
- Parallel or Island operation
- Integration & Interoperability
- Demand response control
- Advanced engines
- PV
- Thermal Energy Storage
- Seamless separation and isolation from utility grid and resynchronization
- Feeder peak load reduction
- Distribution system control of exporting power



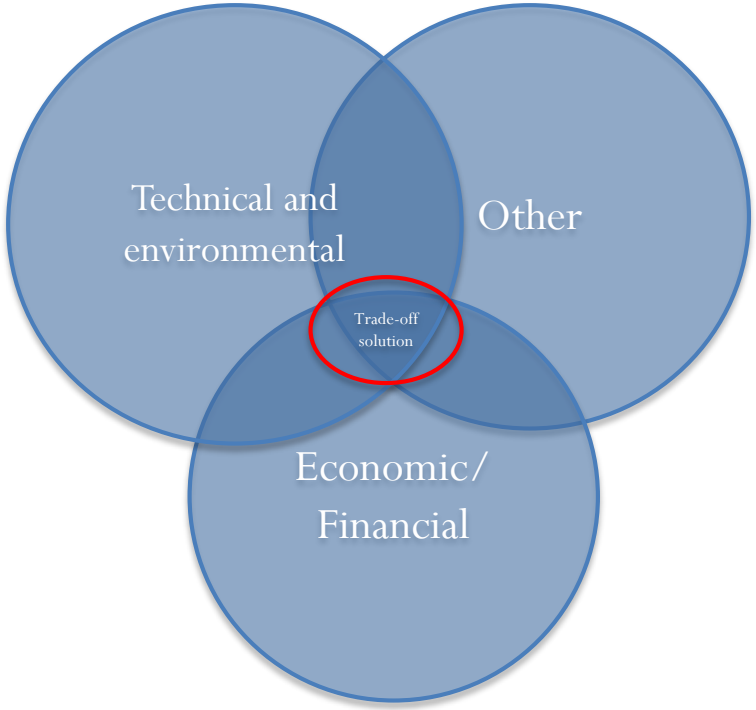
Trends in microgrid development

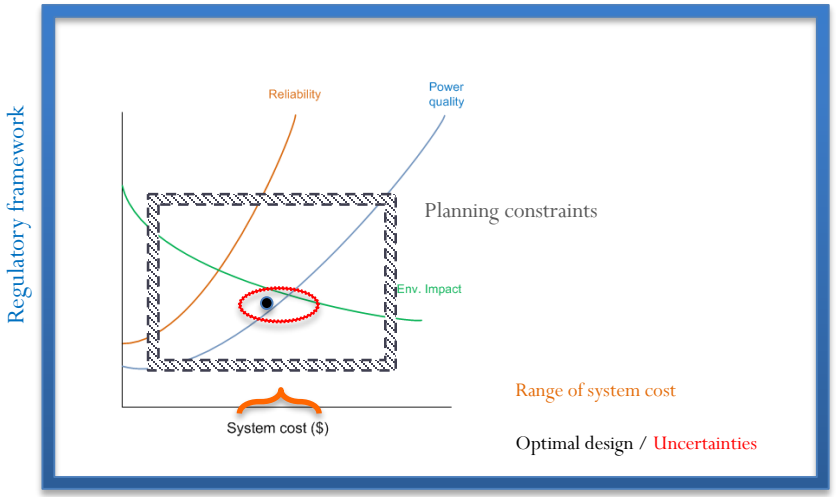
Trends in microgrid development

- CHP is a proven solution
  - Allows a certain penetration ratio of Alternative Energy (10-30%) with minimal engineering
  - CHP technologies make good Anchor resources
  - Variable Loads, Variable Load Banks, EESS
- Growing Desire for High Renewable Energy Penetration and Energy Storage Systems
- Remember: around a 40% of the microgrids are currently based on CHP systems.

Technology	Electrical Output	Emissions	Load Following Ability	Technology Maturity
Natural Gas Reciprocating Engine	Synchronous	Medium	Medium	High
Fuel Cell	Inverter	Low	Low-Medium	Medium-High
Microturbine	Inverter	Low	Medium-High	Medium-High
Gas Turbine	Synchronous	Low	Medium-High	High
Diesel Reciprocating Engine	Synchronous	High	High	High
Battery Energy Storage	Inverter	Zero	High	Medium
Solar PV	Inverter	Zero	Low	High
Wind Turbine	Inverter	Zero	Low	High

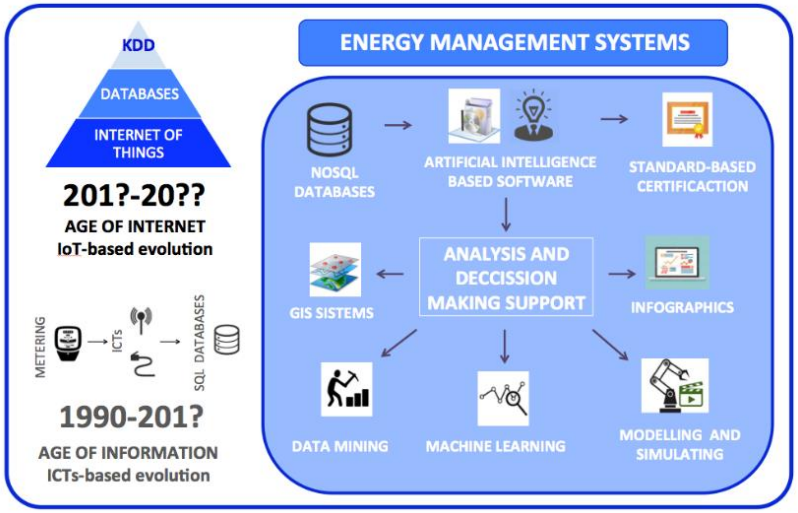
Trends in microgrid planning





Trends in microgrid planning

- ✓ A microgrid planning process is a study of present and future profitability scenarios.
- ✓ Design and planning stages must be strongly focused around specific goals, e.g. save money, save energy, and save environmental emissions.
- ✓ Specific competitive advantages must be the basis of the planning process. **Incentives will support the system only in the short-term.**

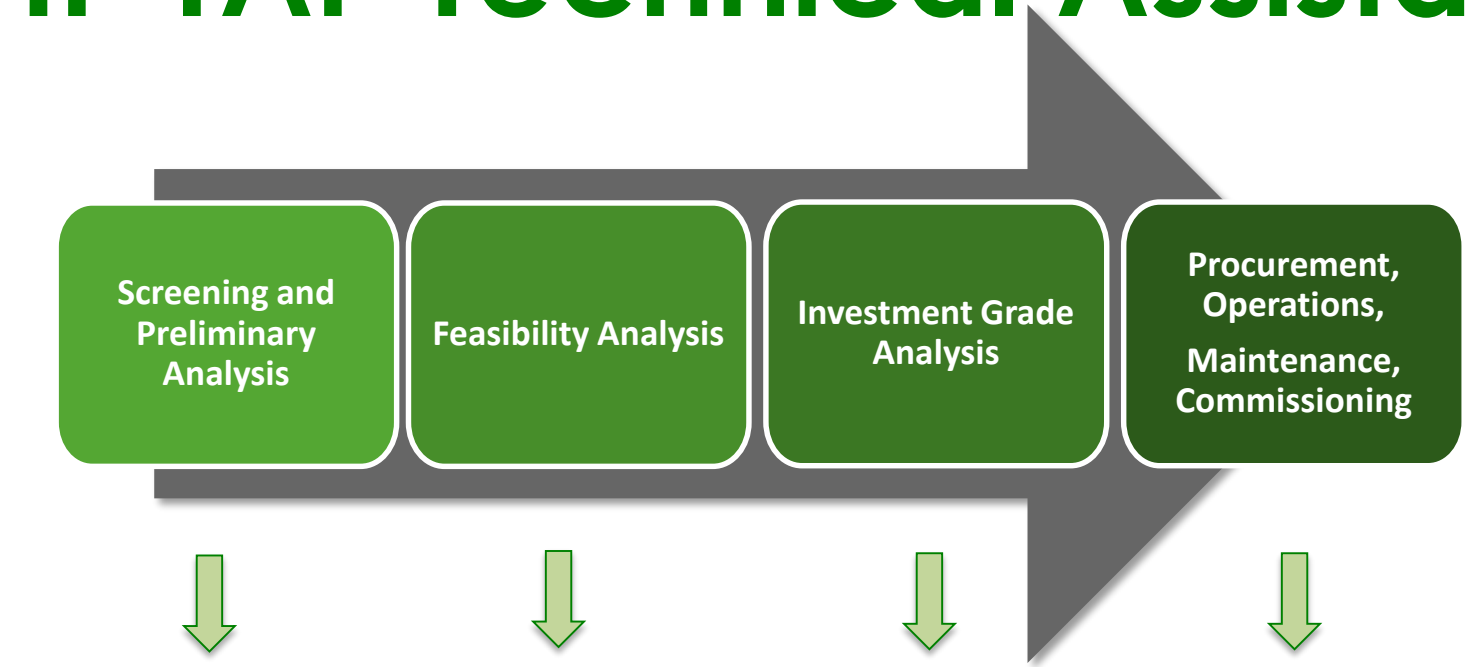


SOURCE: **Evolution and trends of industrial Energy Management Systems.** Gamarra, C.,Montero, E.. IX Congreso Nacional de Ingeniería Térmica. Cartagena (Spain). 2015

- ✓ Tailored solutions vs modular MG.
- ✓ Internet of Things → Holistic approach to energy systems planning.
- ✓ **Facility managers should explore their potential to take advantage of CHP and microgrids.**

Working with the CHP TAP to Assess Project Opportunity

CHP TAP Technical Assistance

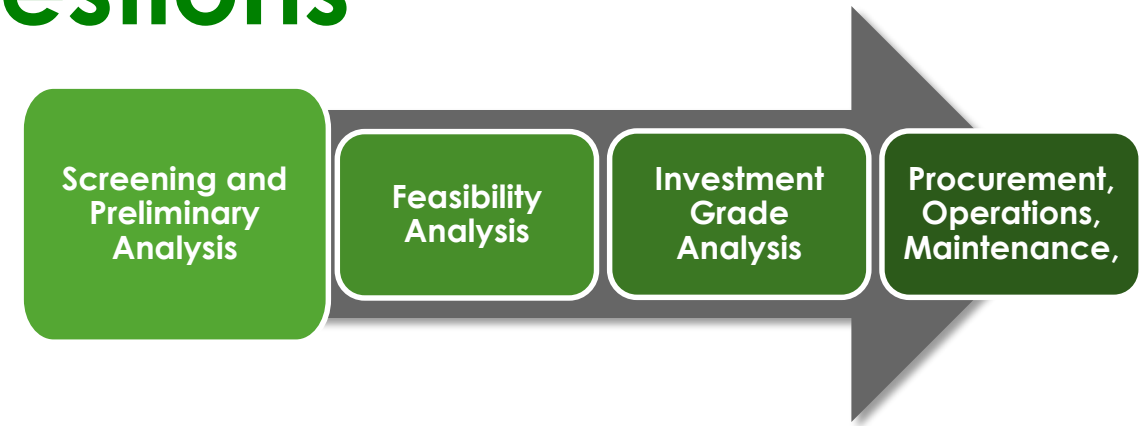


CHP TAP Screening Analysis

- **High level assessment to determine if site shows potential for a CHP project**
  - **Qualitative Analysis**
    - **Energy Consumption & Costs**
    - **Estimated Energy Savings & Simply Payback**
    - **CHP System Sizing**
  - **Quantitative Analysis**
    - **Understanding project drivers**
    - **Understanding site peculiarities**
- **Contact DOE CHP TAP today for complimentary screening**

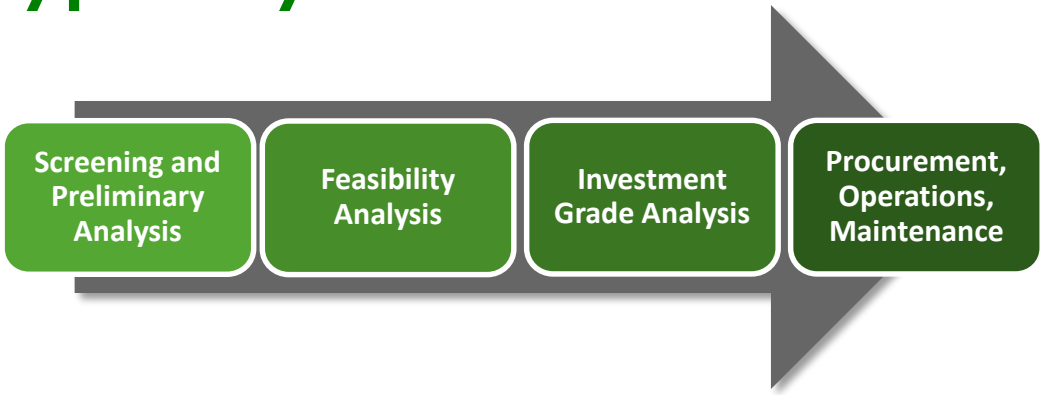
Annual Energy Consumption	Base Case	CHP Case
Purchased Electricty, kWh	88,250,160	5,534,150
Generated Electricity, kWh	0	82,716,010
On-site Thermal, MMBtu	426,000	18,872
CHP Thermal, MMBtu	0	407,128
Boiler Fuel, MMBtu	532,500	23,590
CHP Fuel, MMBtu	0	969,845
Total Fuel, MMBtu	532,500	993,435
Annual Operating Costs		
Purchased Electricity, $	$7,060,013	$1,104,460
Standby Power, $	$0	$0
On-site Thermal Fuel, $	$3,195,000	$141,539
CHP Fuel, $	$0	$5,819,071
Incremental O&M, $	$0	$744,444
Total Operating Costs, $	$10,255,013	$7,809,514
Simple Payback		
Annual Operating Savings, $		$2,445,499
Total Installed Costs, $/kW		$1,400
Total Installed Costs, $/k		$12,990,000
Simple Payback, Years		5.3
Operating Costs to Generate		
Fuel Costs, $/kWh		$0.070
Thermal Credit, $/kWh		($0.037)
Incremental O&M, $/kWh		$0.009
Total Operating Costs to Generate, $/kWh		$0.042

Screening Questions



- Do you pay more than $.06/kWh on average for electricity (including generation, transmission and distribution)?
- Are you concerned about the impact of current or future energy costs on your operations?
- Are you concerned about power reliability? What if the power goes out for 5 minutes… for 1 hour?
- Does your facility operate for more than 3,000 hours per year?
- Do you have thermal loads throughout the year? (including steam, hot water, chilled water, hot air, etc.)

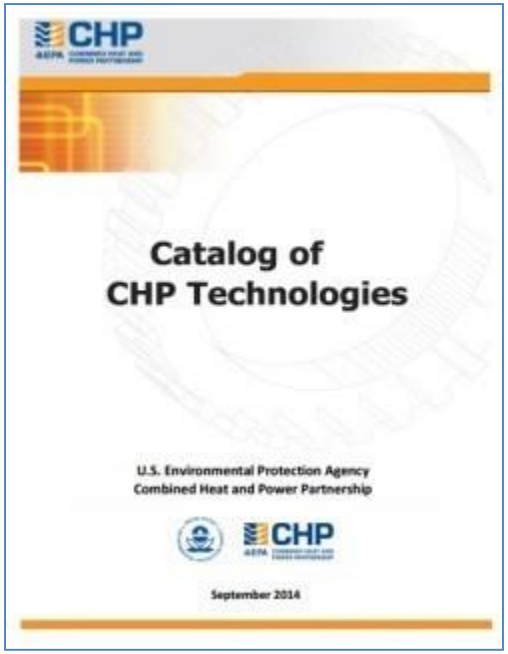
A Feasibility Analysis Typically Involves:



- Electrical load profiling
- Thermal load profiling
- Unit sizing
- Thermal use determination (what to do with the heat)
- Installation cost estimations
- Financial calculations (simple payback, ROI, etc.)
- Cost/savings information compared to what your facility would pay if the CHP system were not installed

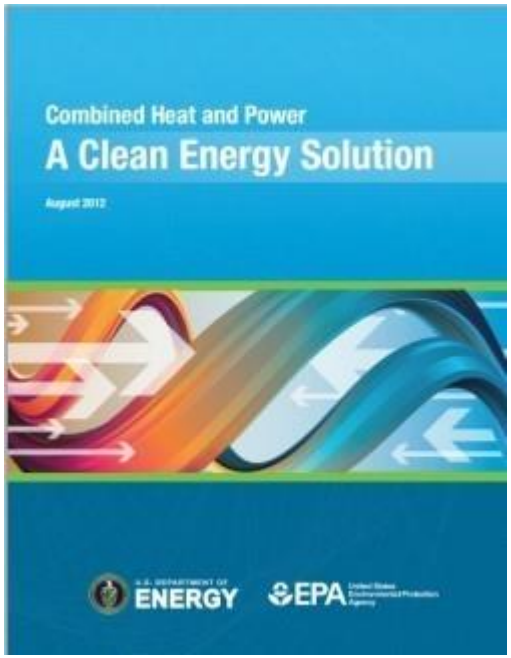
CHP Project Resources

1. DOE/EPA Catalog of CHP Technologies (updated 2014)



http://www.epa.gov/chp/technologies.html

2. Good Primer Report



http://energy.gov/sites/prod/files/2013/11/f4/chp_clean_energy_solution.pdf

CHP Project Resources

3. Project Profile Database (150+ case studies)

www.southwestchptap.org/profiles (scroll down)

4. DOE Database of Incentives & Policies (DSIRE)

www.dsireusa.org

Next Steps

Resources are available to assist in developing CHP Projects.

Contact the Southwest CHP TAP to:

- Perform CHP Qualification Screening for a particular facility
- Identify existing CHP sites for Project Profiles
- Additional Technical Assistance

Summary

- CHP plays a key role in microgrid providing energy savings, reduced emissions, and opportunities for resiliency
- Emerging drivers are creating new opportunities to evaluate CHP and numerous example exist to learn more how other microgrids have incorporated CHP
- Engage with the US DOE Southwest CHP TAP to learn more about the technical assistance offerings in evaluating CHP in your facility

Thank You!

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