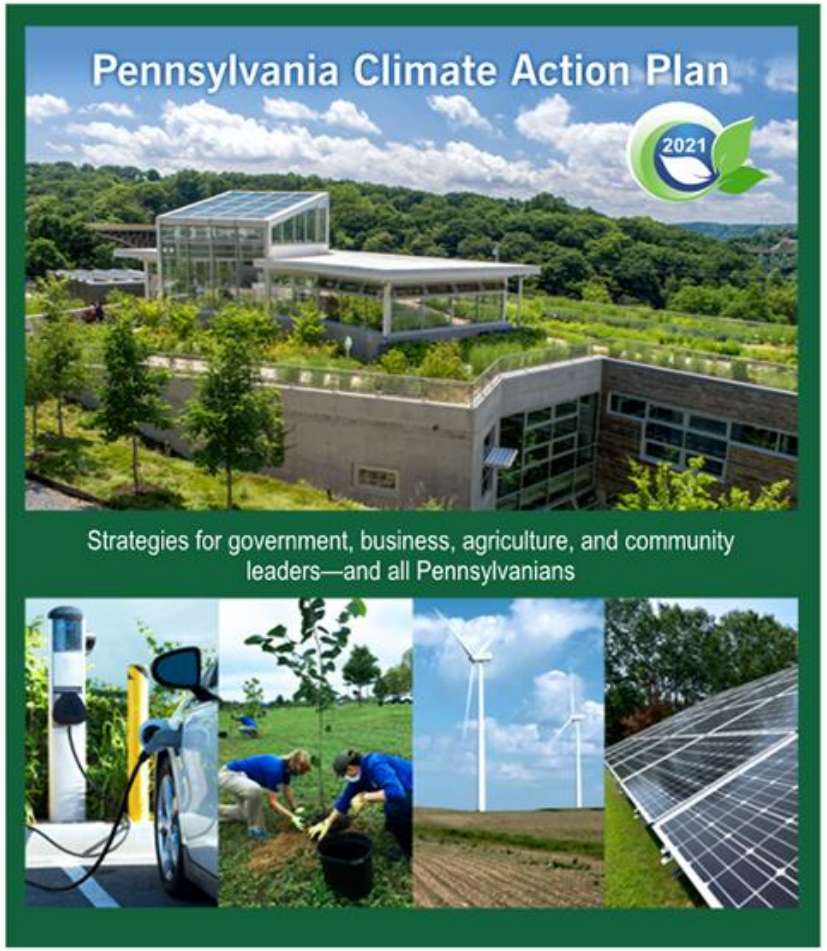
Climate Change Advisory Committee (CCAC)

Oct. 25, 2022

Emerging Roles of CHP-Anchored Distributed Energy:

- **Decarbonization**
- **Energy Resiliency**
- **Food Resiliency & Equity**



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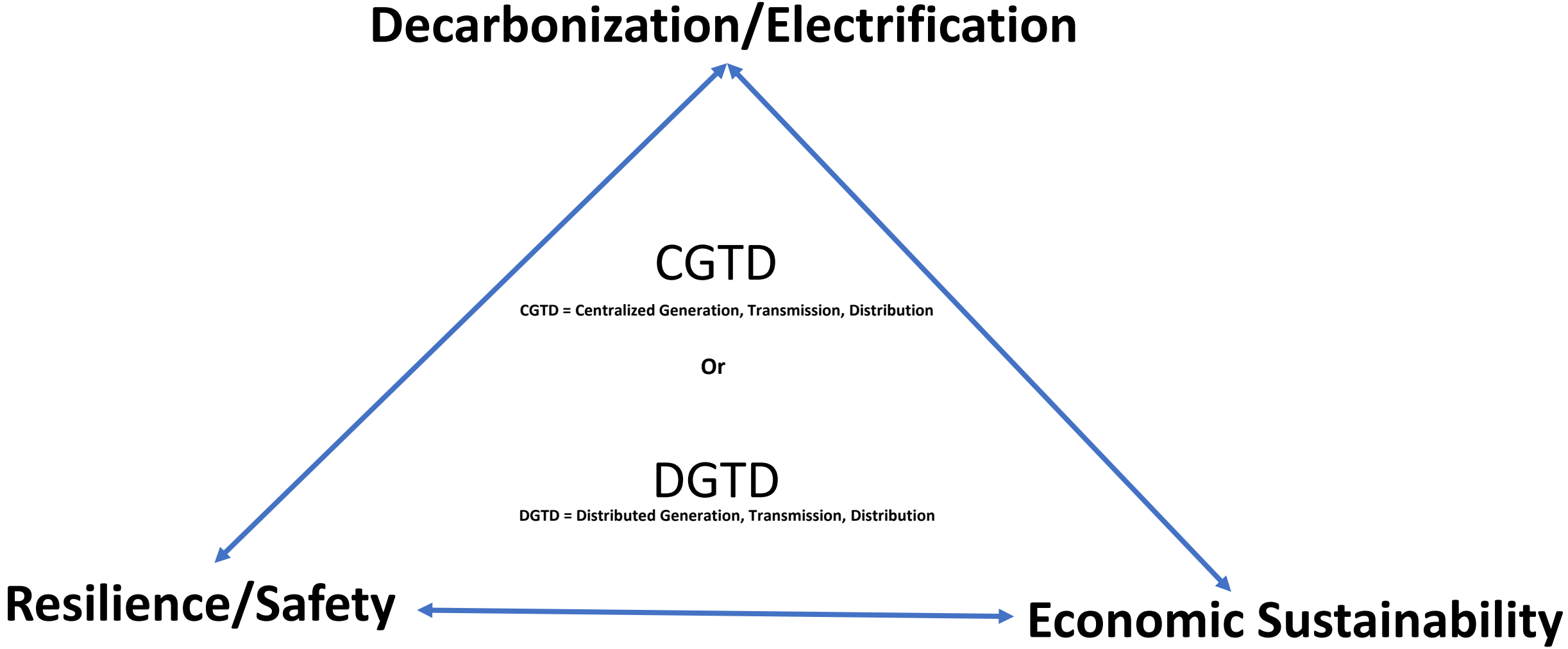
Drivers for Evolution of U.S. Energy Infrastructure

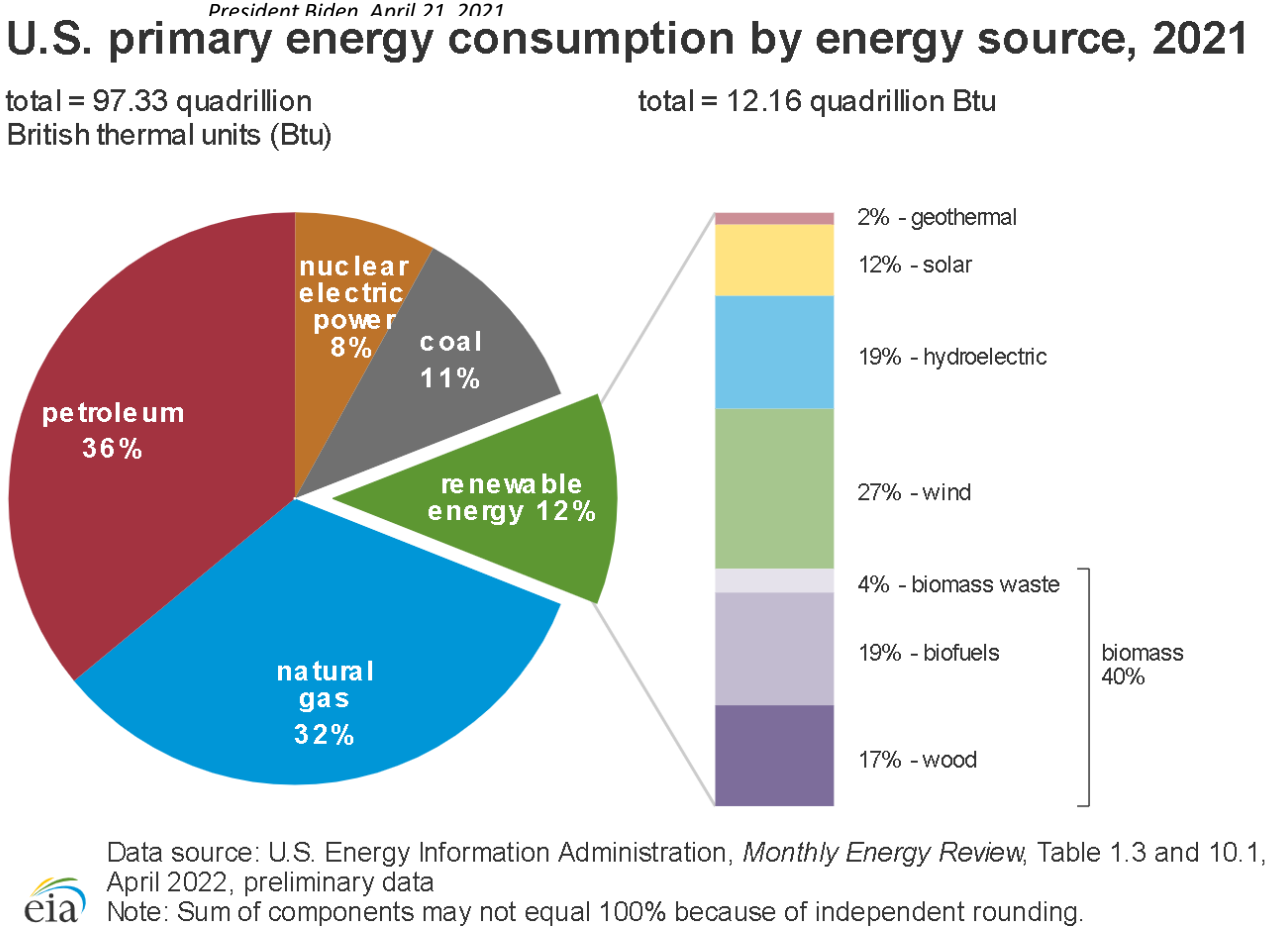


The Path to Decarbonization

- Reducing carbon today is important
- Achieving a net-zero carbon future will require a historic transformation
  - Cost of new generation and T&D
  - Cost of storage
  - Some industrial processes difficult to electrify
  - Critical facilities need dispatchable on-site power for long duration resilience and reliability
  - A renewable grid will need dispatchable generation for support
- Renewable Fuels/RNG/Hydrogen increasingly looked at as part of the solution

Carbon free power sector by 2035
Net-zero carbon emissions by 2050

President Biden, April 21, 2021



Data source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 1.3 and 10.1, April 2022, preliminary data
Note: Sum of components may not equal 100% because of independent rounding.

CGTD

CGTD = Centralized Generation, Transmission, Distribution

Top Down

U.S. Energy Infrastructure Decarbonization/Electrification

Bottoms Up

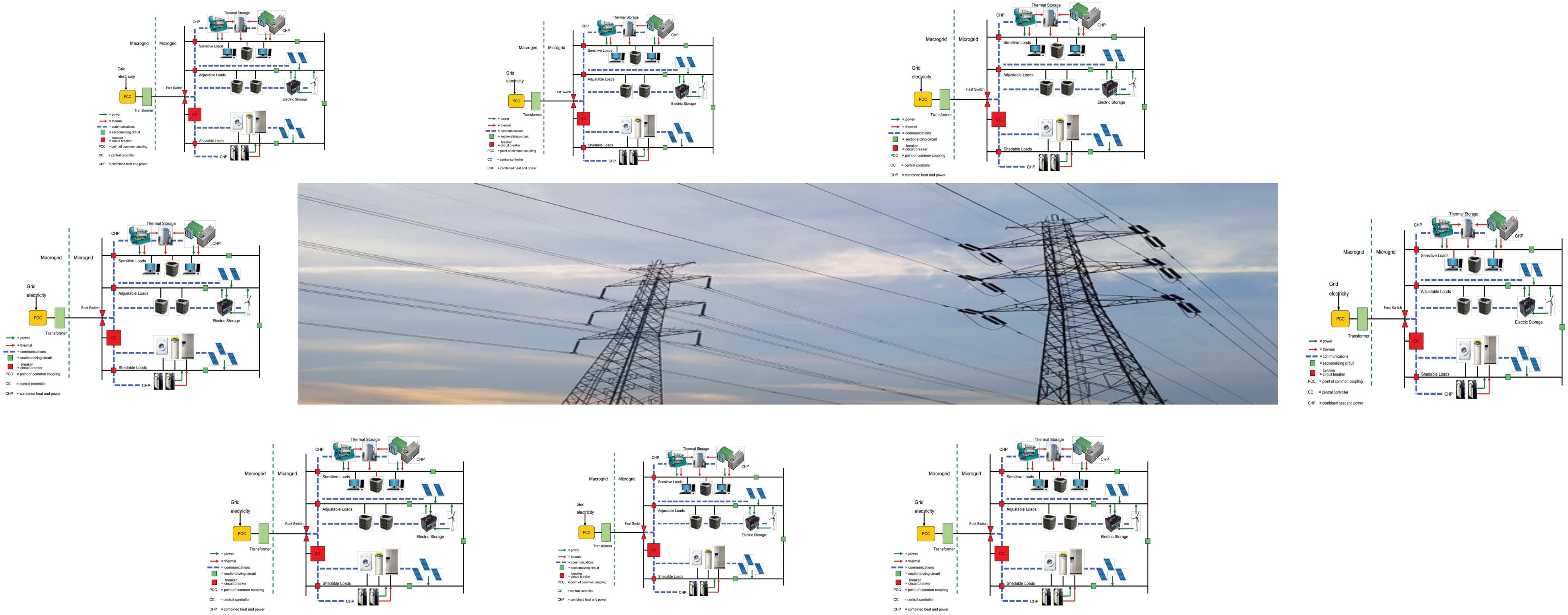
DGTD = Distributed Generation, Transmission, Distribution

DGTD

Renewable Energy CGTD Paradigm
Top Down Decarbonization

Does Not Address CGTD Resiliency Vulnerability Risks!!!
Economic Costs Not Well Defined
Local Community Economic Sustainability Not Addressed

RECES DGTD Paradigm
Bottoms up Decarbonization



Enables Community Resiliency +Decarbonization + Economic Sustainability !!!

U.S. Department of Energy
CHP Technical Assistance Partnerships
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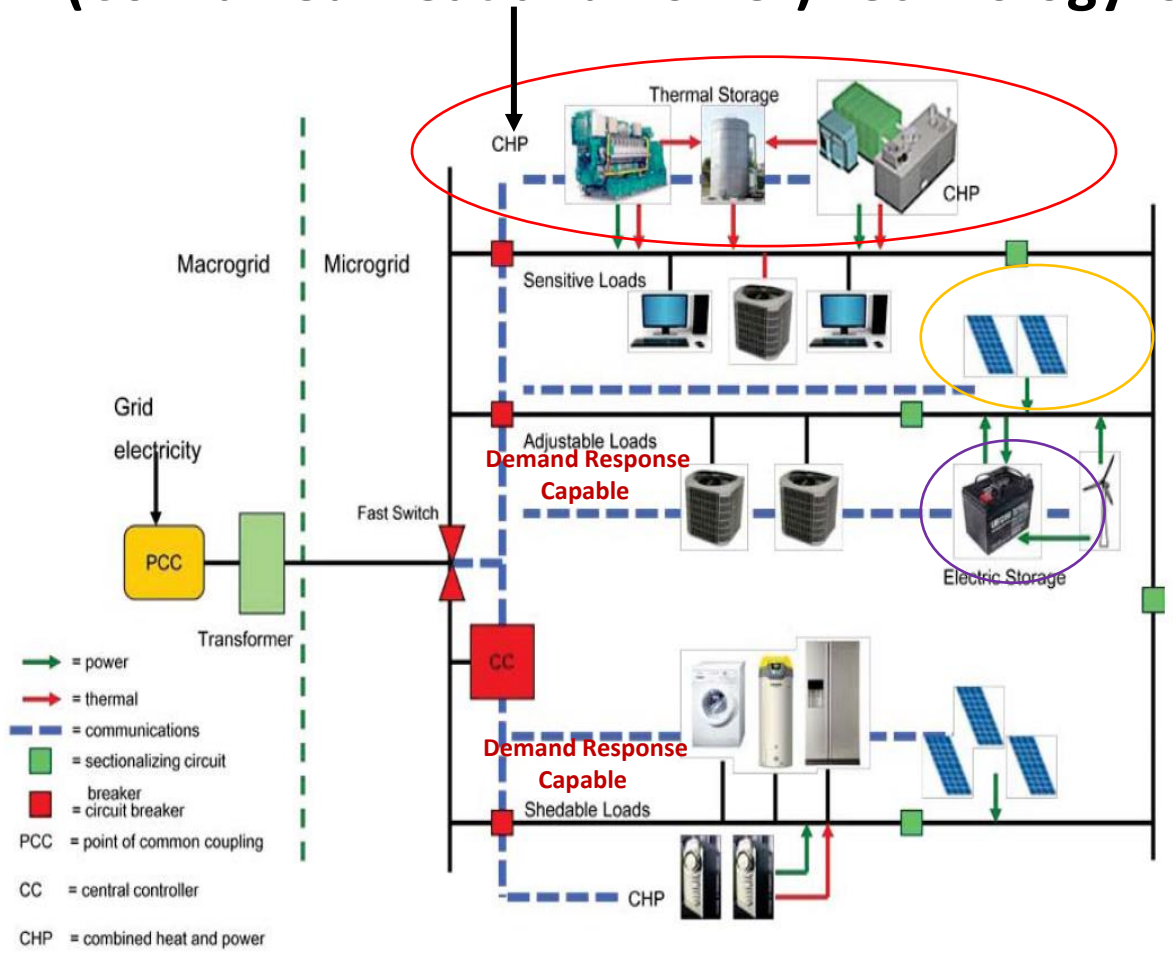
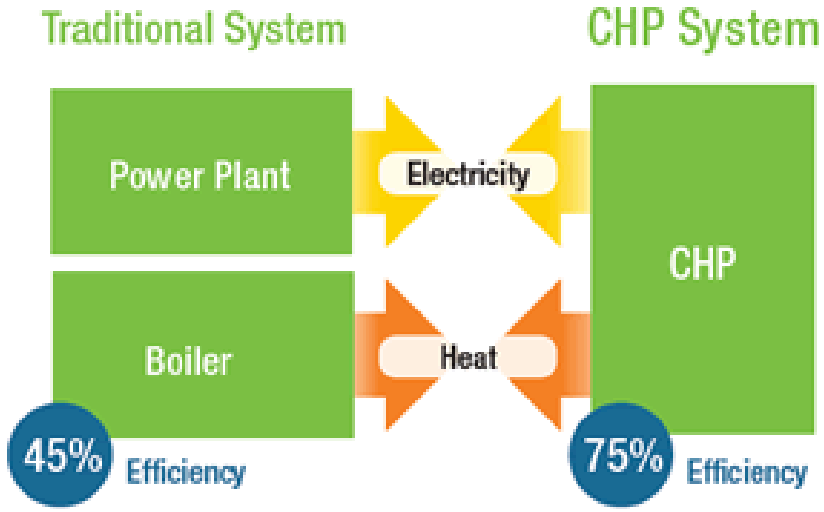
RECES: Renewable Energy Community Energy Systems

CHP (Combined Heat and Power) Technology is an Enabler



What is CHP?

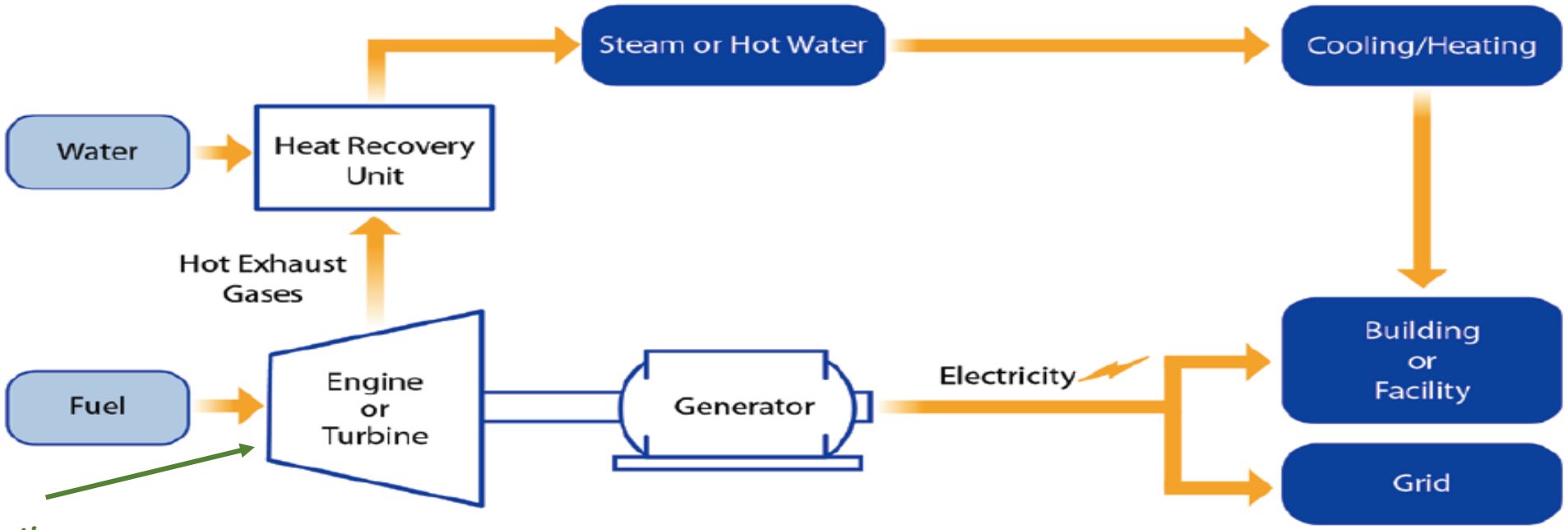
- Form of Distributed Generation (DG)
- An integrated system
- Located at or near a building / facility/community
- Provides at least a portion of the electrical load and
- Uses thermal energy for:
  - Space Heating / Cooling
  - Process Heating / Cooling
  - Refrigeration/Dehumidification



Source: http://www1.eere.energy.gov/manufacturing/distributedenergy/chp_basics.html

CHP provides cost-effetive, clean and reliable energy – today and for the future.

CHP System Components

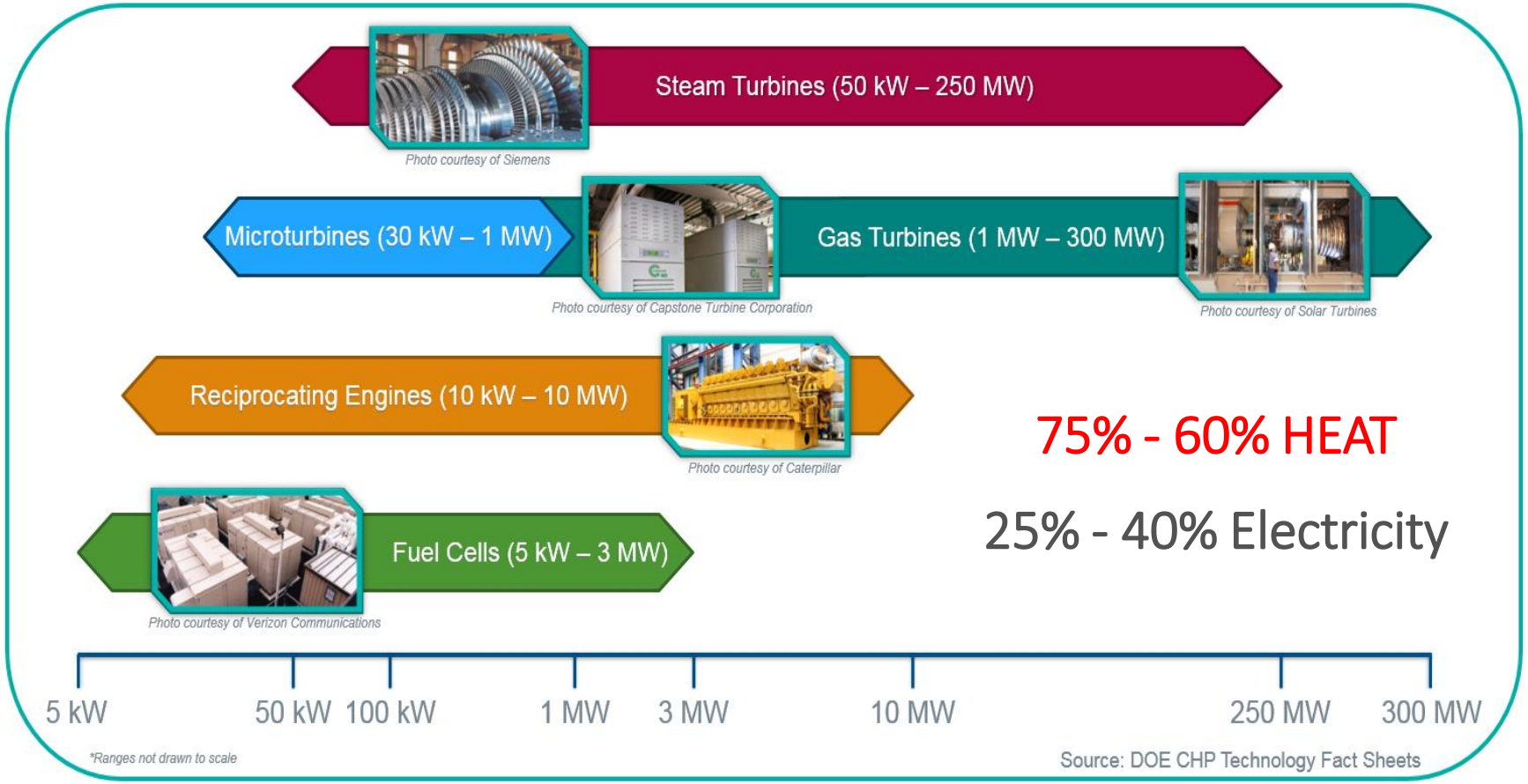


Cost-effective engine modifications enable use of H_2 and RNG fuels

- Prime Mover
- Heat Recovery
- Thermal Technology
- Accessory Devices

- Switchgear
- Interconnection
- Fuel Supply
- Controls/M&V

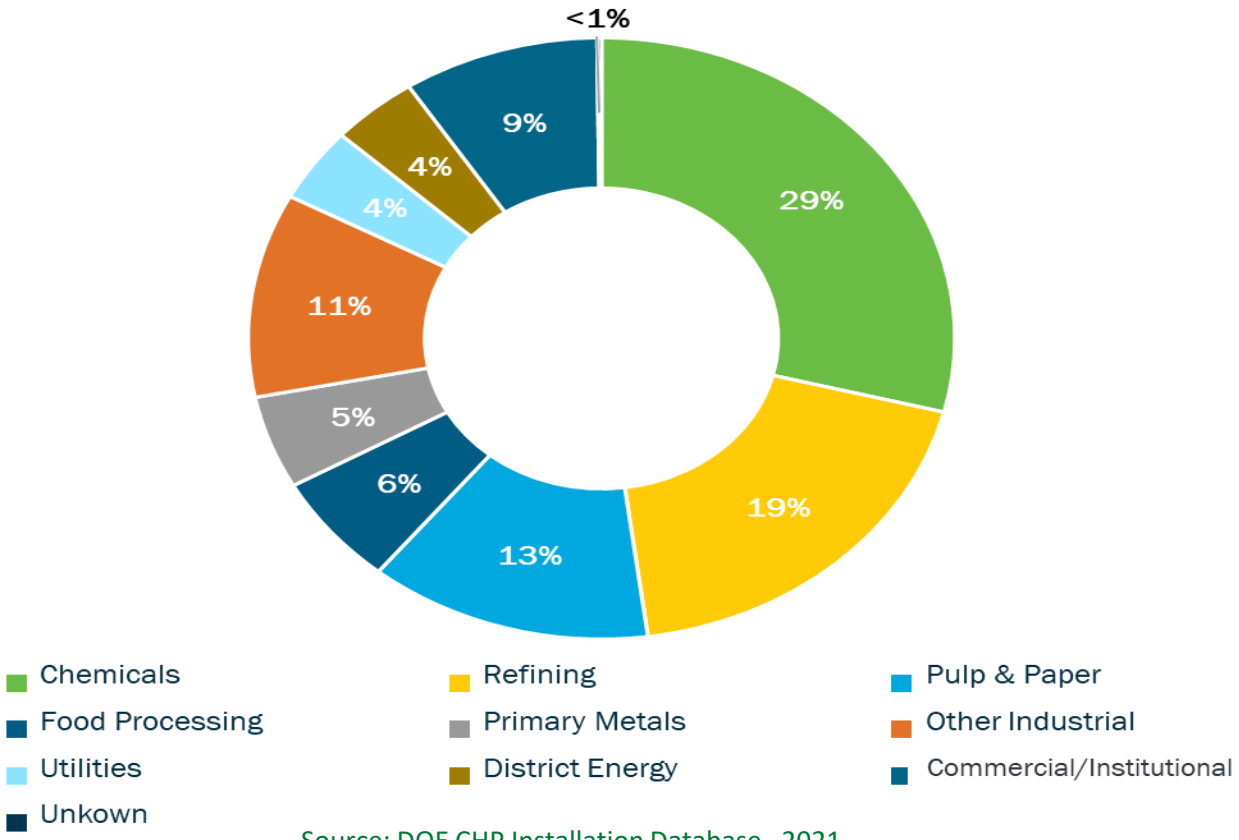
Common CHP Technologies and Capacity Ranges



All engine manufacturers are adapting combustion processes of engines to be able to operate off of blends of H_2 and RNG or 100% H_2 or RNG, i.e. capable of net zero carbon operation!

CHP Today in the United States

Existing CHP Capacity: 81.7 GW



Source: DOE CHP Installation Database, 2021

Avoids more than **1.3 quadrillion Btus** of fuel consumption annually.

Avoids **215 million metric tons of CO^2** compared to separate production.

81.7 GW of installed CHP at more than **4,700** industrial and

7% of U.S. electric generating capacity

U.S. Department of Energy
CHP Technical Assistance Partnerships
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CHP's High Efficiency Saves CO_2 Emissions Today

- CHP and renewables **displace marginal grid generation (including T&D losses)**
- Marginal generation is **currently a mix of coal and natural gas** in most regions of the US
- **CHP's high efficiency and high annual capacity factor** currently results in significant annual energy and emissions savings
- CHP's efficiency **advantages will continue as the gas infrastructure decarbonizes**
- *"Because emissions are cumulative and because we have a limited amount of time to reduce them, carbon reductions now have more value than carbon reductions in the future"*

Source: "Time Value of Carbon", Larry Strain, Carbon Leadership Forum, April 2020

Category	Natural Gas CHP	Utility Solar PV	Utility Wind	Biogas CHP
Capacity, MW	20.0	20.0	20.0	20.0
Annual Capacity Factor	90%	24.3%	34.3%	90%
Annual Electricity, MWh	157,680	42,574	60,094	157,680
Annual Thermal Provided, MWh_{th}	169,466	None	None	169,466
Annual Energy Savings, MMBtu	**628,000**	**382,992**	**540,002**	**628,300**
Annual CO_2 Savings, Tons	**70,114**	**32,654**	**46,092**	**163,187**
Annual NOx Savings, Tons	53.5	16.4	23.1	53.5

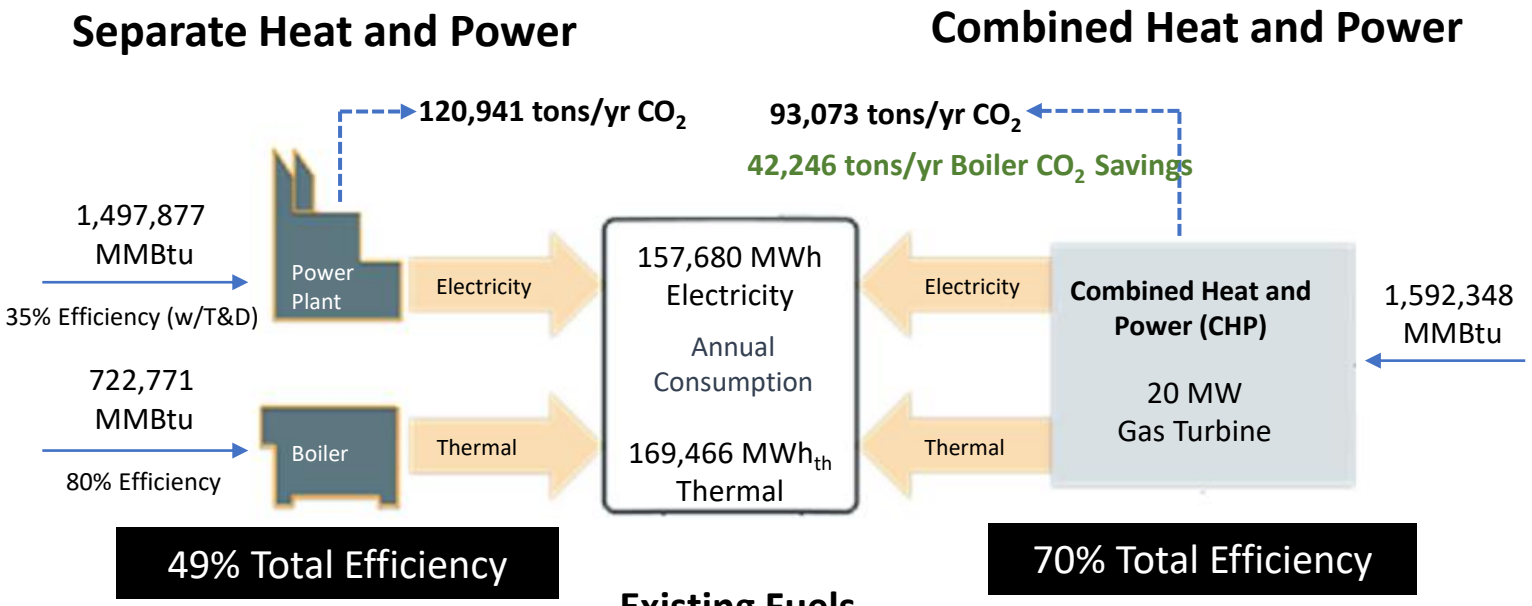
Savings based on EPA AVERT Uniform EE Emissions Factors as a first level estimate of displaced marginal generation (https://www.epa.gov/avert)

Prepared by: Entropy Research, LLC, 7/28/2022

CHP Provides both Energy and CO_2 Emissions Savings

20 MW Gas Turbine CHP System

- Natural gas fuel
- 90% load factor (7,884 hours)
- 33.8% electric efficiency
- 75.7 MMBtu/hr steam output
- 100% thermal utilization
- Displaces 80% efficient natural gas boiler
- CO_2 savings based on displacing EPA AVERT Uniform EE grid emissions factor (1,534 lbs CO_2/MWh)



Existing Fuels

Energy savings:	628,300 MMBtu/yr
Total* CO_2 Savings:	70,114 tons/yr

***Includes Grid Marginal Electricity CO_2 Savings**

If Distributed Green H_2 + RNG Available net $CO2_e$ for Operation = 0!

CHP System Emissions Advantage

A 2.5 MW CHP plant located in PA demonstrates a 26% reduction in CO_2e or 3,675 tons per year according to the US EPA CHP Emissions Calculator.

Figure 1. Conventional Production Energy Flow Schematic

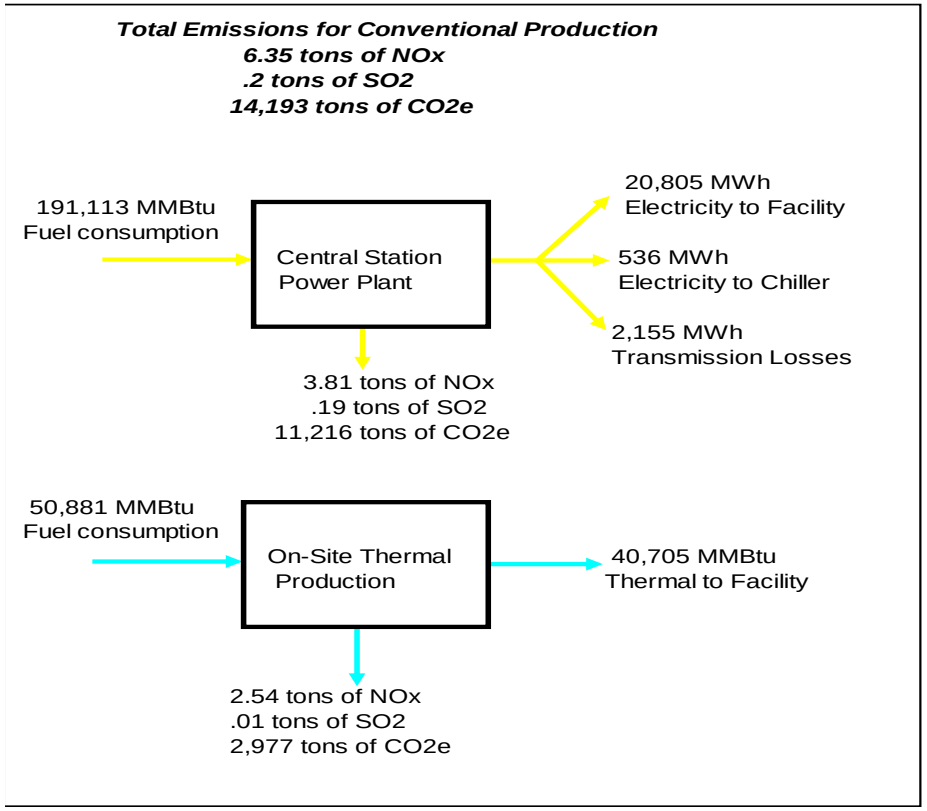
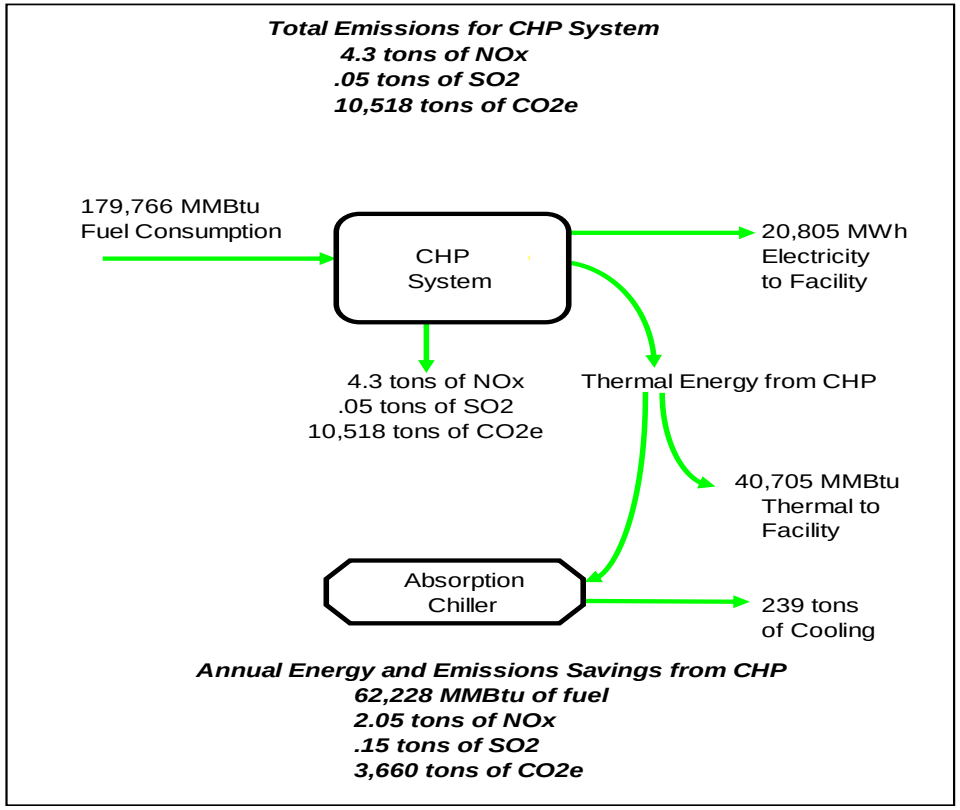


Figure 2. CHP System Energy Flow Schematic



Operating Economics Snapshots

Upper Chesapeake Medical Center, Bel Air, MD

- Installed in 2016
- 2.0 MW CHP with 350 ton chiller
- Natural gas reciprocating engine producing steam, chilled water, and hot water
- $450,000 in energy savings per year

Supreme Sports Club, Columbia, MD

- Installed in 2016
- 60 kW CHP with hot water heat recovery
- Natural gas reciprocating engine producing space, pool water and DHW heating
- $96,500 in energy savings each year

Project Snapshot:

Cost Savings

Yuengling Brewery

Pottsville, PA

Application/Industry: Brewery

Capacity: 400 kW; CHP covers 20% of total electricity needs

Prime Mover: Reciprocating engine

Fuel Type: Digester gas and natural gas

Thermal Use: Pasteurization

Installation Year: 2014

Testimonial: *"It's called combined heat and power because we generate power but also generate waste heat and that waste heat is going to be used to heat our pasteurization process. We'll use less steam to heat our tunnel pasteurizer because we're preheating the water with the heat from the CHP system…It's definitely ahead of the curve on technology, and a huge jump forward."* - Robert Seaman Jr., Yuengling Plant Manager

Project Snapshot:
Manufacturing

Proctor & Gamble

Mehoopany, PA

Application/Industry: Paper products

Capacity: 64 MW

Prime Mover: Combustion Turbine

Fuel Type: Marcellus Natural gas

Thermal Use: Manufacturing process (steam and drying)

Installation Year: 2013

Energy Savings: $16.5M each year

Highlights:

- Proctor& Gamble's largest manufacturing facility in the world
- CHP part of an effort to save money and reduce CO2 emissions
- Export 480 MWH per day

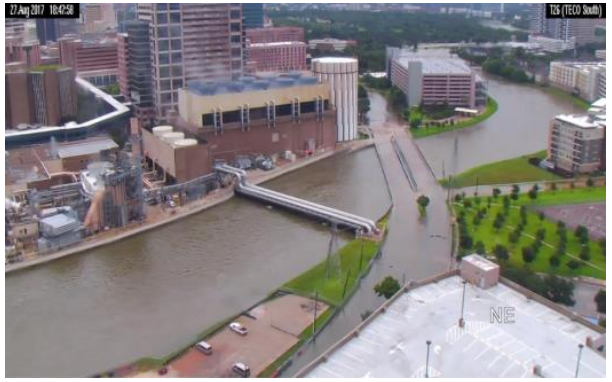
Issue Brief – Examining the Performance of Different DERs in Disaster Events

Natural Disaster or Storm Events	Flooding	High Winds	Earthquakes	Wildfires	Snow/Ice	Extreme Temperature
Battery Storage	◒	○	◒	●	○	◒
Biomass/Biogas CHP	◒	◒	◒	●	○	○
Distributed Solar	○	◒	◒	●	◒	◒
Distributed Wind	○	◒	◒	◒	◒	◒
Natural Gas CHP	○	○	◒	◒	○	○
Standby Generators	◒	○	◒	●	◒	○

https://betterbuildingsinitiative.energy.gov/sites/default/files/attachments/DER_Disaster_Impacts_Issue%20Brief.pdf

Project Snapshot: Texas Medical Center

- Location: Houston, TX
- Application/Industry: Hospital
- Capacity: 48 MW
- Prime Mover: Combustion turbine
- Fuel Type: Natural gas
- Thermal Use: Steam for heating and chilled water
- Installation Year: 2010
- Resilience Benefits
  - Provided critical services to hospital patients and staff throughout Hurricane Harvey
  - Elevated CHP system design was able to withstand flooding given significant storm surge in the area
  - Also provides $6-12 million in energy cost savings per year



Brays Bayou before and after flooding from Hurricane Harvey, photos courtesy of the Thermal Energy Corporation (TECO)

Project Snapshot: Sikorsky Aircraft Corporation

- Location: Stratford, CT
- Application/Industry: Manufacturing
- Capacity: 10.7 MW
- Prime Mover: Gas turbine
- Fuel Type: Natural gas
- Thermal Use: Steam for heating and steam turbine chiller
- Installation Year: 2011
- Resilience Benefits
  - Facility was fully operational during Hurricane Sandy, when the surrounding area was out of power for over a week
  - Facility provided disaster relief helicopter transport services and provided community services for ~6,650 employees and their families during and after the storm

SIKORSKY
A LOCKHEED MARTIN COMPANY

Sikorsky Aircraft CHP system, photos courtesy of Sikorsky Aircraft Corporation

Project Snapshot: POET Biorefining and City of Macon, MO

- Location: Macon, MO
- Application/Industry: Chemicals and City/Community
- Capacity: 10 MW
- Prime Mover: Gas Turbine
- Fuel Type: Natural gas
- Thermal Use: Steam and hot water
- Installation Year: 2007
- Resilience Benefits
  - The CHP system provides steam to the POET plant and electricity to the surrounding community
  - CHP has allowed the facility to avoid multiple grid outages since 2007, leading to no lost revenue and reliable electricity for the surrounding community

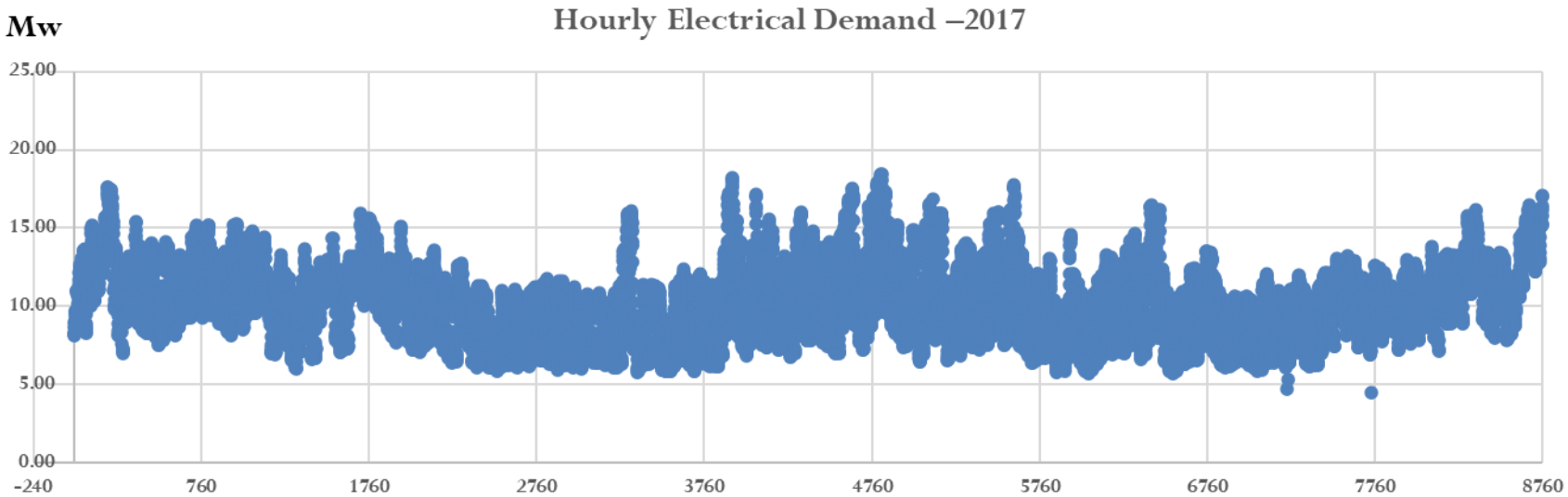
POET Biorefining Facility, photos courtesy of POET and U.S. DOE

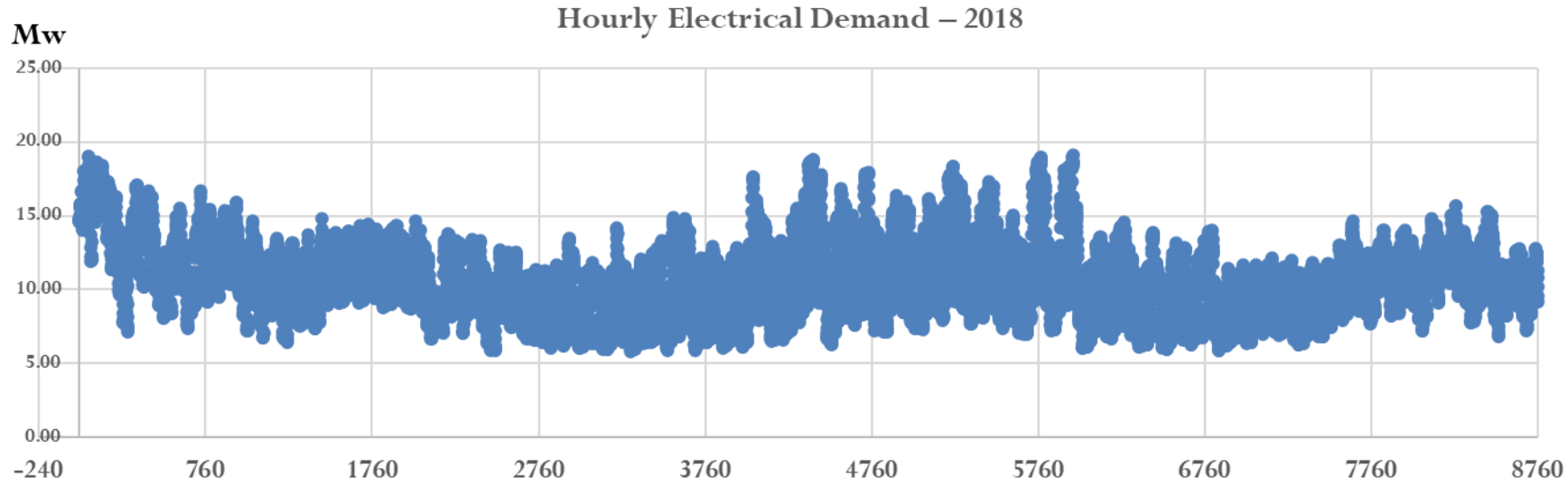
Project Snapshot: Hospital De La Concepcion

- Location: San German, Puerto Rico
- Application/Industry: Hospitals
- Capacity: 1.2 MW
- Prime Mover: Recip. engine
- Fuel Type: Propane
- Thermal Use: Steam for space heating/cooling, DHW and refrigeration
- Installation Year: 2017
- Resilience Benefits
  - Operates in 100% island mode, isolated from the electric grid
  - Provided critical power and thermal energy to the hospital during and after Hurricane Maria
  - CHP also allows for significant energy cost savings

HOSPITAL DE LA CONCEPCION


SEAL OF THE BOROUGH OF QUAKERTOWN
INCORPORATED 1855
BUCKS CO., PA.
Walmart Supercenter
N Old Bethlehem Pike
Portzer Rd
W Broad St
309
313
California Rd
Heller Rd
212
N Hellertown Ave
JP's Diner
E Broad St
Quaker Color
Trumbauersville Rd
309
Google
Paletown


Hourly Electrical Demand –2017
Mw
25.00
20.00
15.00
10.00
5.00
0.00
-240
760
1760
2760
3760
4760
5760
6760
7760
8760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760
1760
2760
3760
4760
5760
6760
7760
8760

CHP + Solar: Quakertown Municipal Grid Implementation

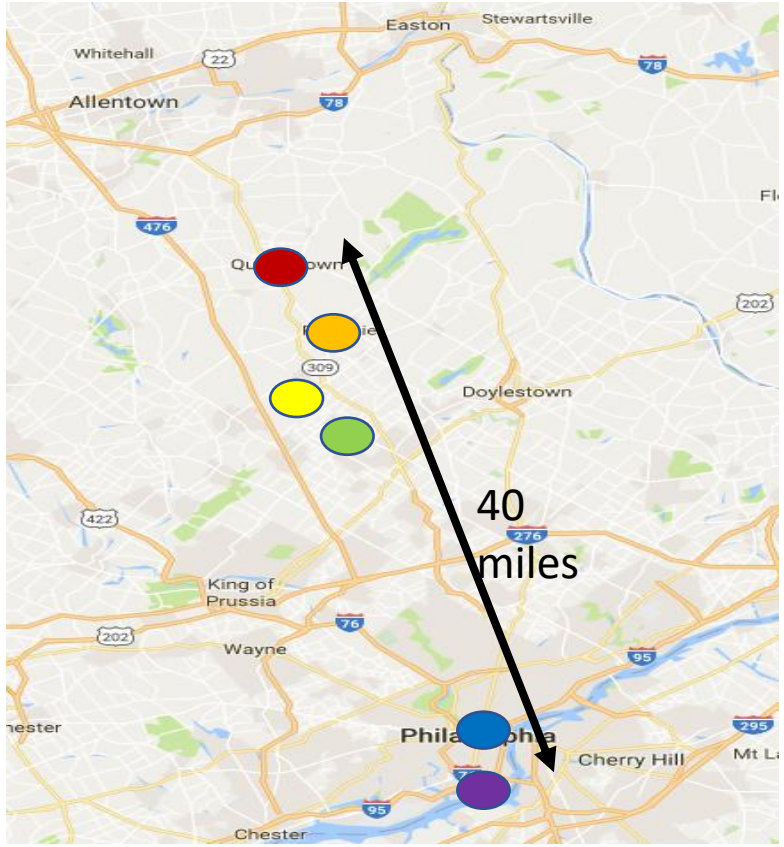
~ 875 kw CHP

~ 1 MW Solar PV

Developing Municipal Utilities Distributed Energy Microgrid

Aligns six independent electric utilities along regional transportation corridors to enable efficient manufacturing, transportation, communications

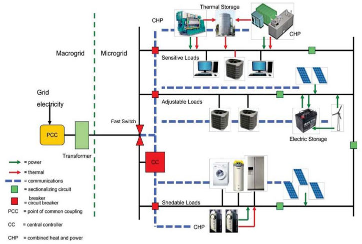
- Quakertown
- Perkasie
- Hatfield
- Lansdale
- Philadelphia
- •Navy Yard

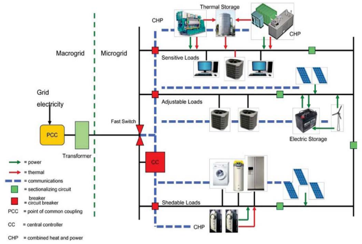


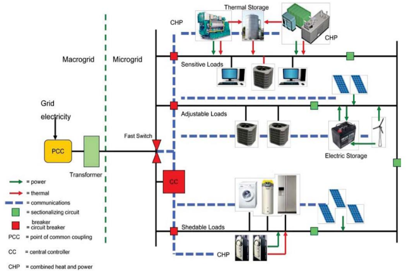
Have ample natural gas supply for transition to green H_2, RNG

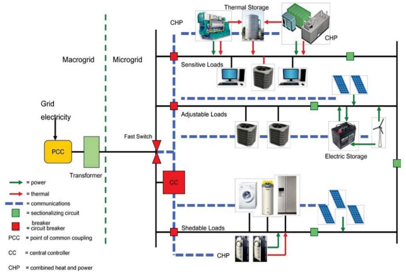
CHP – Based Microgrid Investigated by Mid-Atlantic CHP as Key Enabler

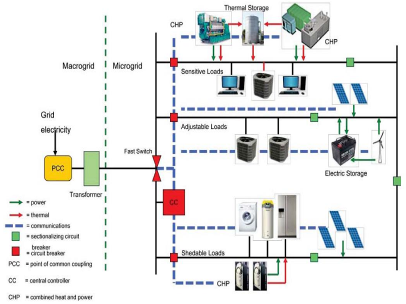
RECES DGTD Paradigm
Bottoms up Decarbonization

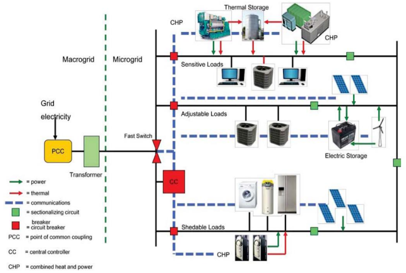


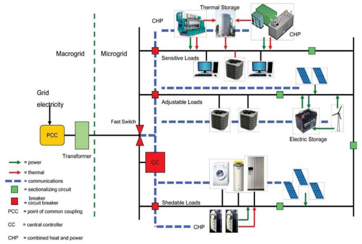


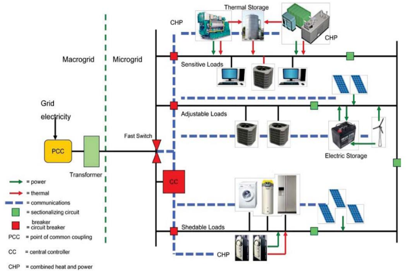












Enables Community Resiliency +Decarbonization + Economic Sustainability !!!

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Drivers for Evolution of U.S. Energy Infrastructure

Decarbonization/Electrification

CGTD

CGTD = Centralized Generation, Transmission, Distribution

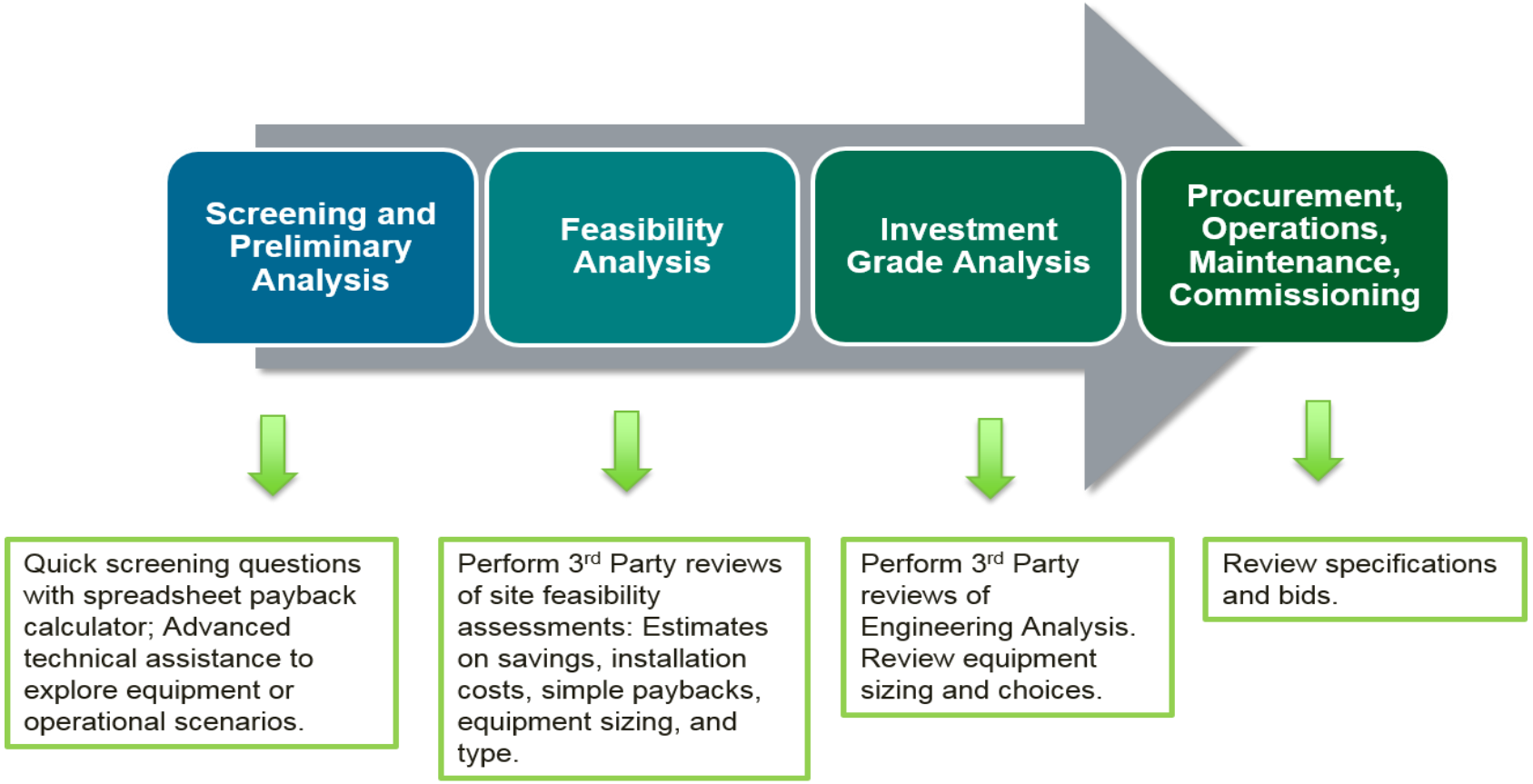
Or

DGTD

DGTD = Distributed Generation, Transmission, Distribution

Resilience/Safety ⟷ **Economic Sustainability**

DOE Mid-Atlantic CHP TAP Role: Technical Assistance

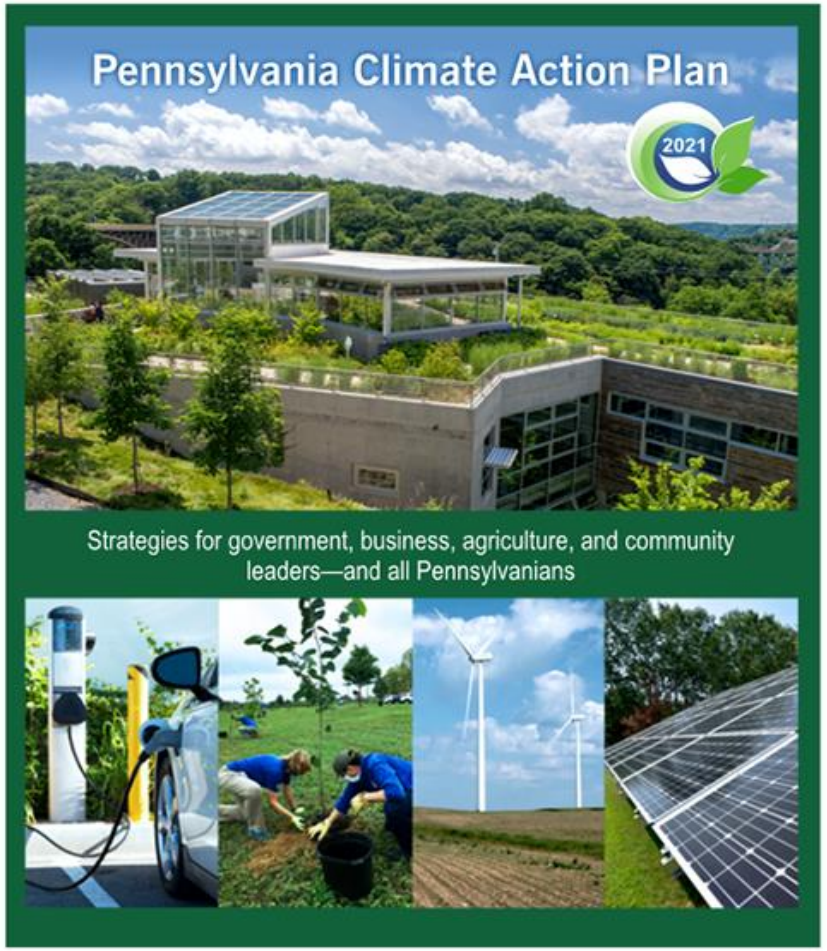


Climate Change Advisory Committee (CCAC)

Oct. 25, 2022

Emerging Roles of CHP-Anchored Distributed Energy:

- **Decarbonization**
- **Energy Resiliency**
- **Food Resiliency & Equity**
- **A Unique PA Opportunity**



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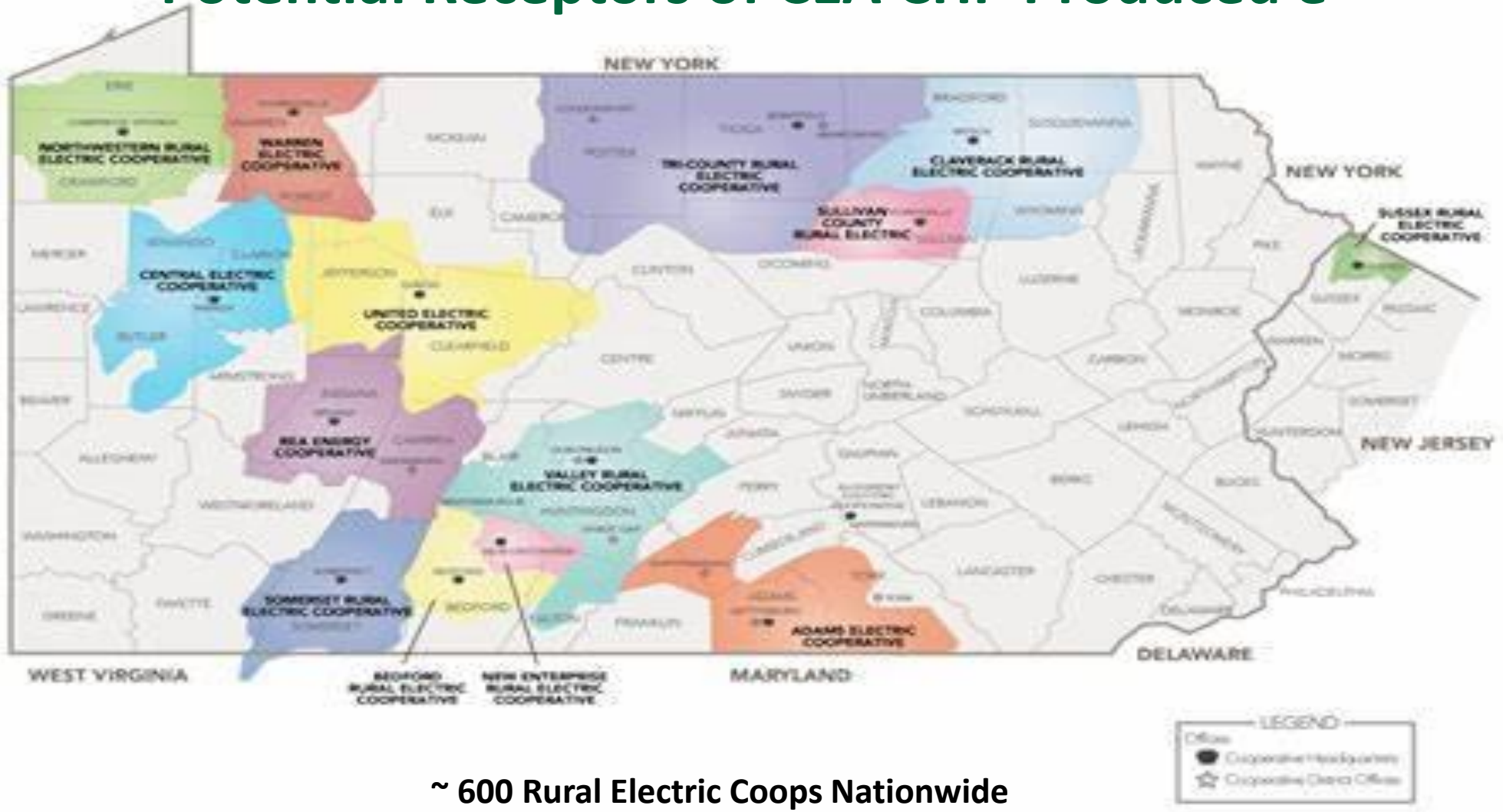
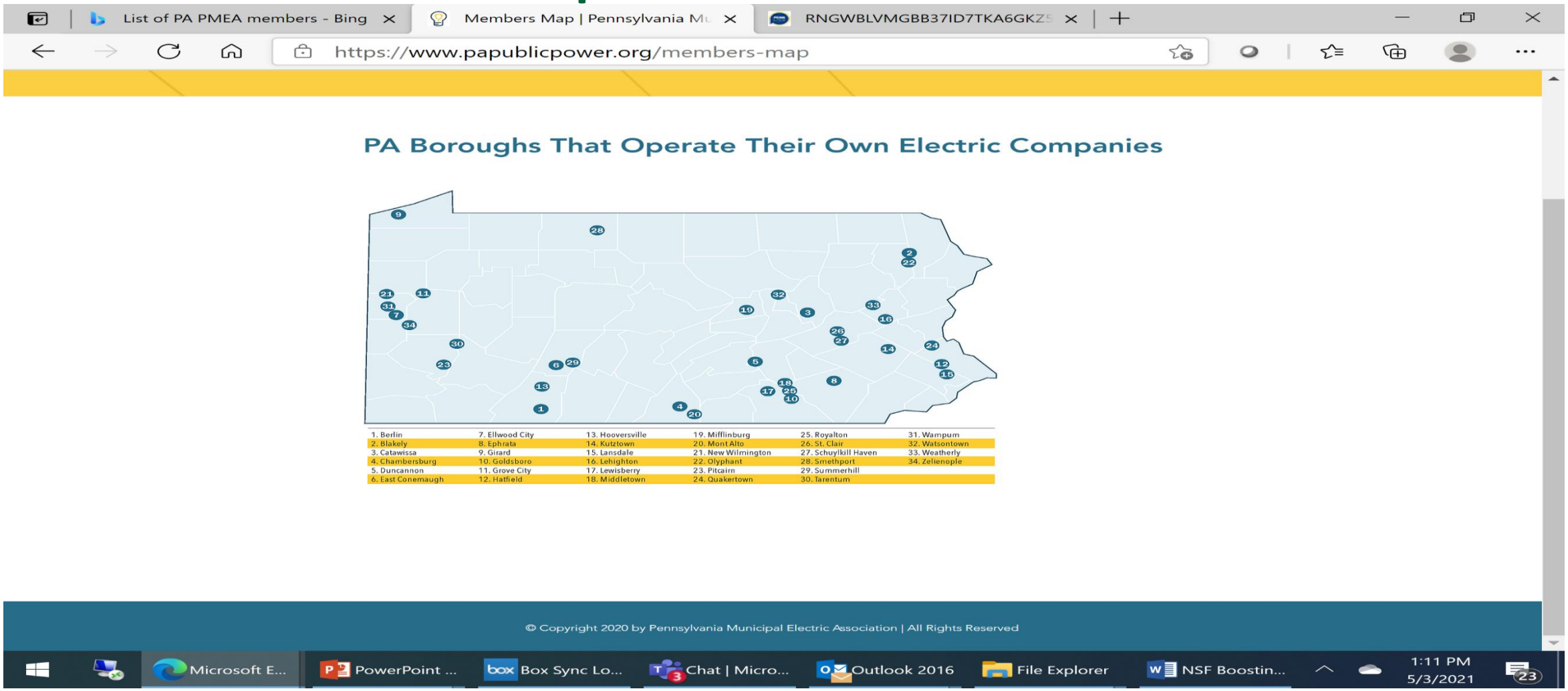
PA Rural Electric Coops (13)
Potential Receptors of CEA CHP Produced e-



~ 600 Rural Electric Coops Nationwide
~ 60% of U.S. Land Mass

PA Municipal Grids (35)
Potential Receptors of CEA CHP Produced e-



~ 2000 Munies Nationwide
Serving ~60 million people

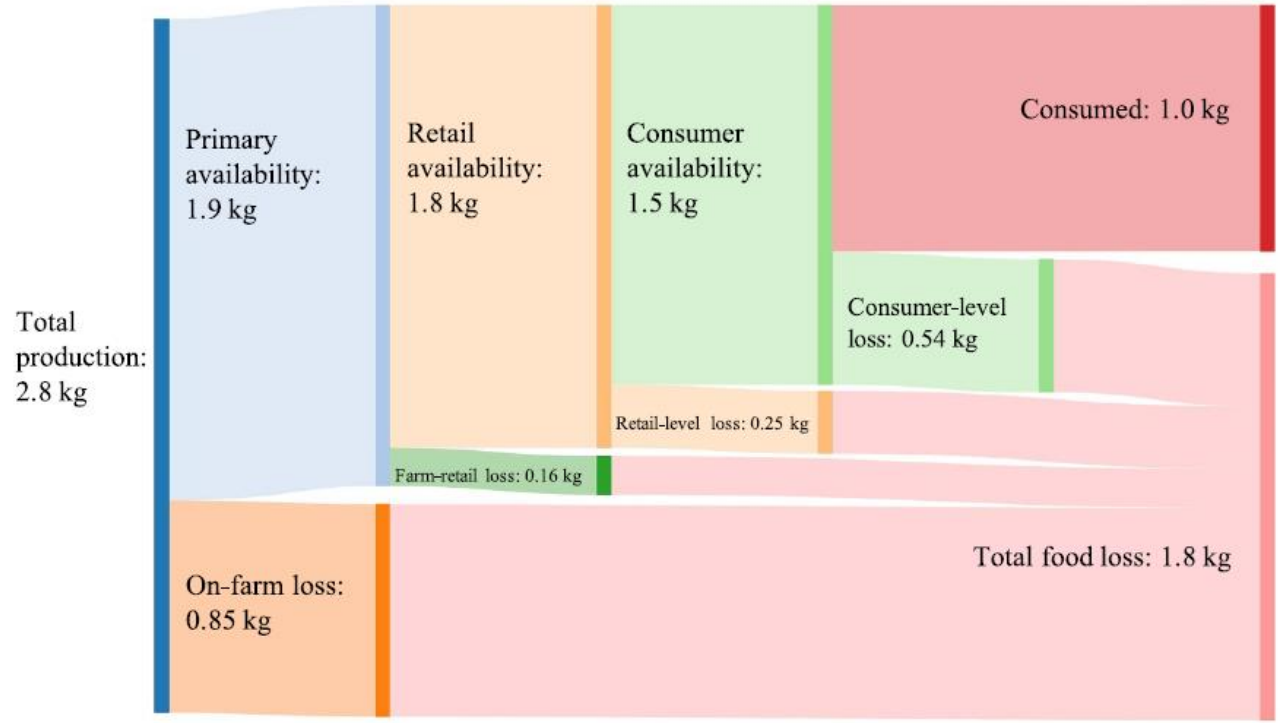
CHP-Enabled Controlled Environment Agriculture in PA

A Component of Decentralized Food Resiliency and Equity

Environmental Impacts of Transporting California Produce Including Food Loss

Flow diagram of assessed food waste stages and processes.

Fragile Fruit Losses: Strawberries



Sankey diagram for the production and food loss of 1 kg of strawberry consumption with 300 km transportation distance.

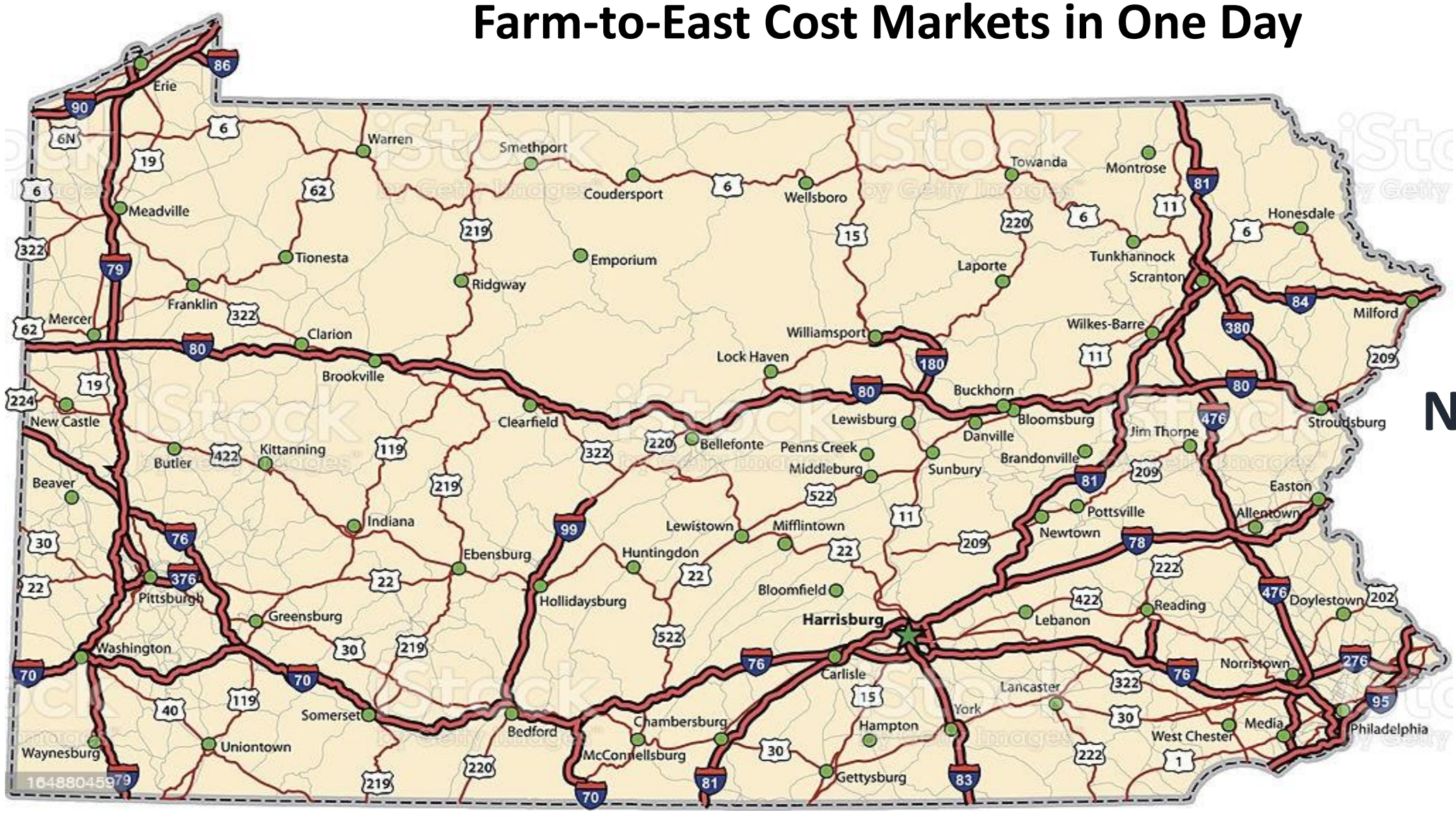
Yuwei Qin and Arpad Horvath, Source: Contribution of food loss to greenhouse gas assessment of high-value agricultural produce: California production, U.S. Consumption, UC, Berkeley, 12/2020

CHP- CEA Greenhouse Agriculture

- Up to 15 times the production of outdoor, open field, farms
- Over 90% of greenhouse yields are marketable fruits and vegetables compared to 40–60 percent marketable produce under field production and transportation to market paradigm (over 50% waster for some produce)
- Dramatic decease in water required compared to open field agriculture paradigm
- Measurable and quantifiable reduction on regional watershed environmental stress via fertilizer insecticide, pesticide run off
- Significant decease in and agricultural related CO_2 emissions compared to current distant, open field – transportation paradigm for produce delivery to market
- Local economic growth – local domestic product growth & jobs (3-4 jobs per acre under glass)
- Increases local grid and food security & resiliencies
- CEA improves increased nutritional food access to local markets

Source: AG incotech, A Modern Solution to Sustainable Food, https://agincotech.com/portfolio/greenhouse-report/

PA Interstate Highway System
Farm-to-East Cost Markets in One Day



New York City

Philadelphia

New Jersey