Propane: A Low Carbon Solution for the Future

Gokul Vishwanathan, Director of Research and Sustainability, Propane Education & Research Council

Propane Education & Research Council

- PERC is a nonprofit that provides leading propane safety and training programs and invests in R&D of new propane-powered technologies. PERC is operated and funded by the propane industry. PERC programs benefit a variety of markets including transportation, agriculture, commercial landscaping, residential, and commercial building.
- PERC was authorized by the U.S. Congress with the passage of the Propane Education and Research Act (PERA), signed into law on Oct. 11, 1996. PERC is governed by a 21-member board appointed by the National Propane Gas Association and the GPA Midstream Association. Each association appoints nine Council members and they cooperate in the appointment of three public members.
- PERC's operations and activities are funded by an assessment levied on each gallon of propane gas at the point it is odorized or imported into the United States.

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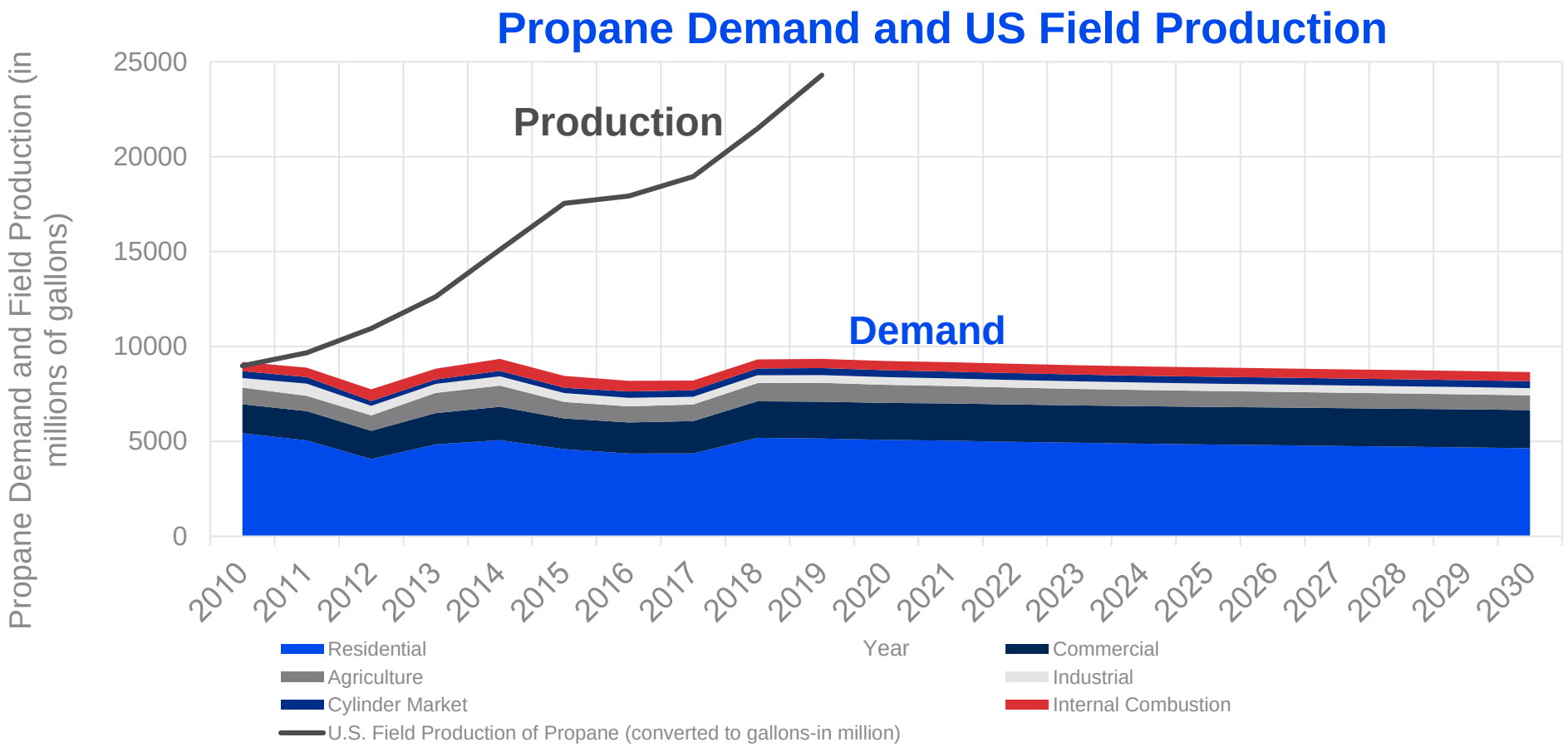
Associate Director of Business Development
Joseph Calhoun

Propane Supply and Demand

- ~**30 billion gallons** of propane produced in US; **~15 billion gallons exported**!



Sources: Annual Retail Propane Sales Report (2018), EIA Annual Energy Outlook (2020)

Sweet-spot of Propane/LPG

Fuel	Liquid volumetric energy density (MJ/l)	C:H	Ease of liquefaction, transportation and storage
Hydrogen	8.5	0	X
Ammonia	11.5	0	✓
Liquefied natural gas[4]	22.2	0.25	X
Propane or LPG	25.3	0.375	✓
Gasoline	34.2	0.5	✓
Diesel	38.6	0.55	✓

Green represents the most desirable property; yellow is the tradeoff and red is undesirable

Distributed Generation

BACKGROUND

What is CHP and what are the benefits of CHP?

- Combined heat and power (CHP) or cogeneration offers tremendous energy benefits compared to centralized power generation due to the following reasons:
  - ~61% of energy is wasted at conventional power plants
  - US Transmission and Distribution (T&D) losses are ~5%
- CHP on the other hand refers to “local” power production at the customer or homeowner’s site
  - No T&D losses
  - Waste energy from the prime mover could be used for heating water, HVAC, dehumidification, heat-to-cooling etc.
  - Overall efficiency could be >90% including both electrical generation efficiency and heat capture efficiency

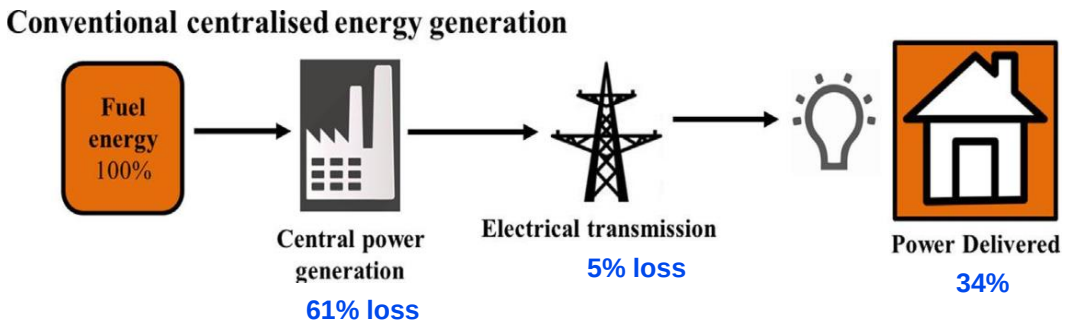


Image Source: Tomal, M. Optimal planning and operation of CHP within micro energy grids (Modified image)

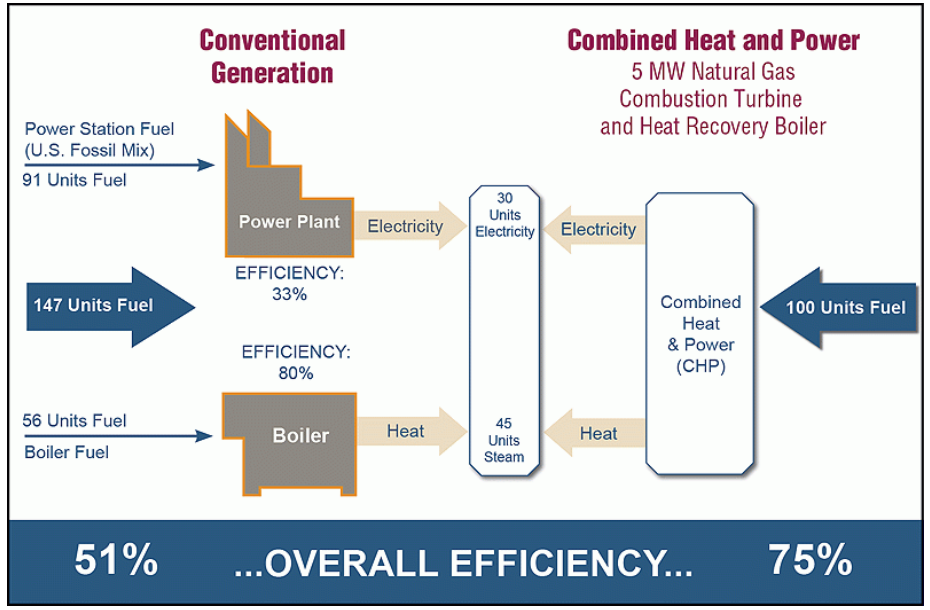
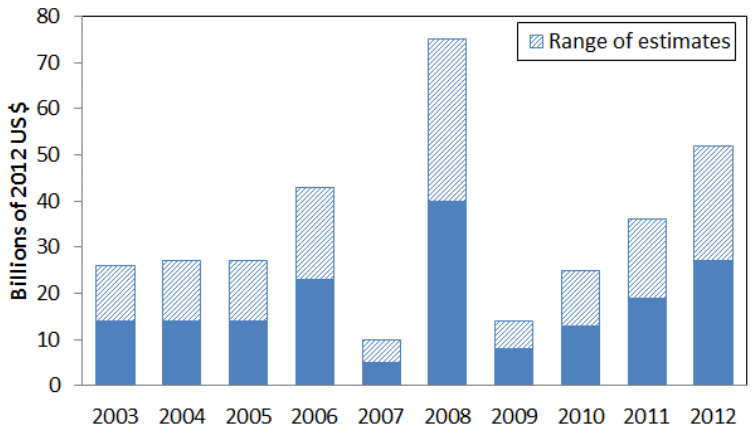


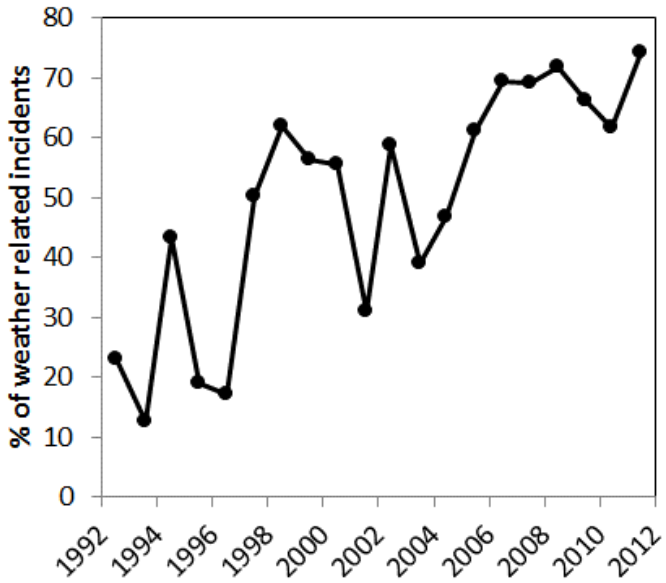
Image Source: https://www.epa.gov/chp/chp-benefits

Sources: LLNL Flowchart, EIA

What are the benefits of CHP?

- Energy Efficiency
- Power resiliency to household and commercial entities offers tremendous economic value
  - Every year, billions of dollars of economic losses are attributed to weather related electricity outages
  - More than 70% of electrical grid disturbances are from weather-related incidents
- *Micro-CHP (mCHP) is loosely defined as CHP units with <50 kW capacity* and that are suitable for residential (single-family, multi-family, buildings etc.) and light commercial applications (hospitals, offices, restaurants, schools etc.)





Sources: Economic Benefits of Increasing Electric Grid Resilience to Weather Outages (2013) and Mills, E.: Electric Grid Disruptions and Extreme Weather. In: US Disaster Reanalysis Workshop, Asheville, NC (2012)

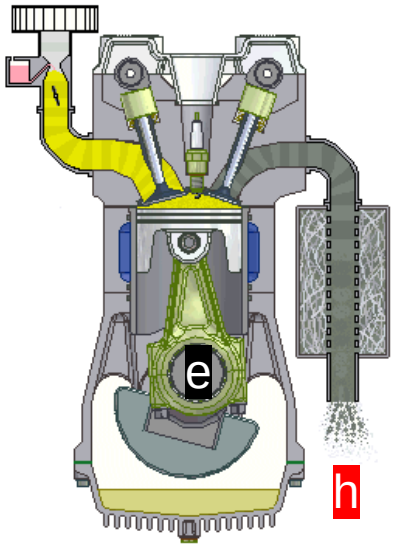
Sizing vs. Application

1-3 kW	3-10 kW	10-50 kW	50 kW - 1 MW
• Medium sized single family homes (~2500 sq.ft.)	• Large single family homes and/or with higher heating needs (e.g. heated swimming pool) • Multi-family • Light commercial (e.g. small office)	• Residential buildings • Commercial applications (e.g. restaurants)	• Large commercial and industrial applications

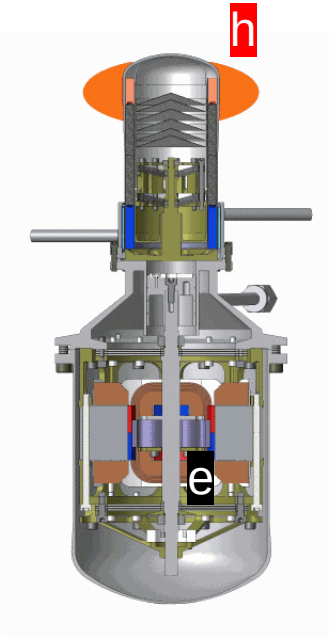
Micro-CHP → Large CHP

Typical Prime Movers

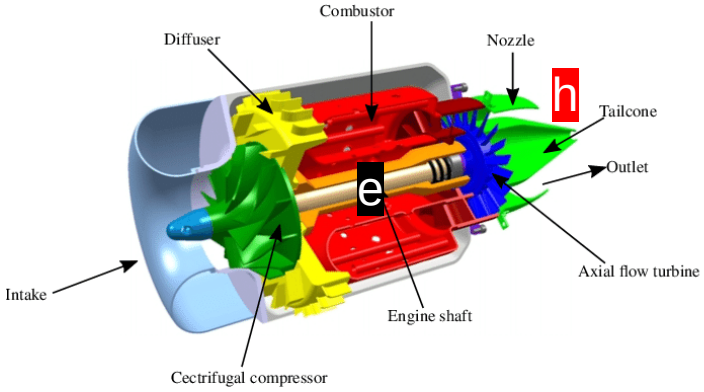
Internal combustion engine - Mechanical



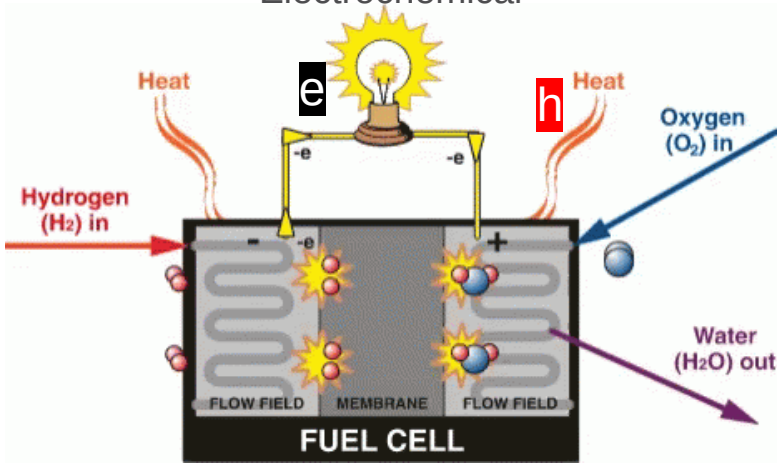
Stirling engine - Mechanical



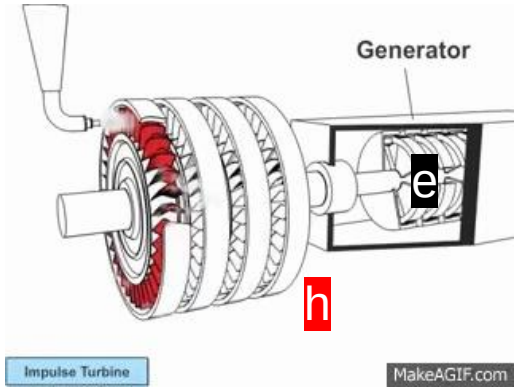
Microturbine - Mechanical



Fuel Cell - Electrochemical



Steam turbine - Mechanical



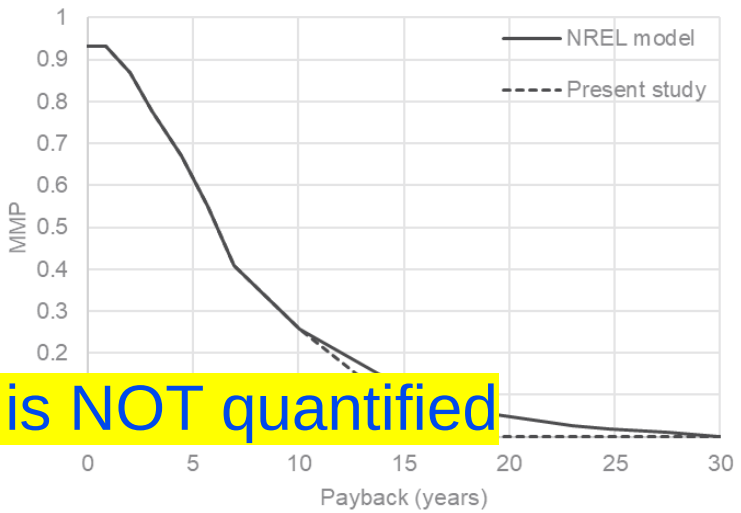
Source: Several internet sources

General Framework of a Simple Techno-economic Market Model

Parameter	Residential	Commercial
Zones	Northeast, Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central and Mountain	
# of establishments	EIA data for each zone that is currently using propane for heating and hot water	
Avg. thermal load (kW)	3.9	20
Capacity factor (-)	0.5	0.7
Avg. electrical generation η (-)	0.25	0.3
Total CHP η (-)		
Price of electricity ($/kWh)	EIA data for March 2020 for each zone	
Price of propane ($/gallon)	Avg. residential EIA data from Oct 19-Mar 20 (or Feb 20-March 20) for each zone	15% discount on residential propane price
Payback (years)	10 (2018 median homeownership length in the U.S. was 13 years)	
MMP (-)	0.2 (Refer to chart)	
Baseline η of propane furnace/heater (-)	0.9	
Device O&M	$0.01/kWh of electricity generated	

Only cost is considered. Value is NOT quantified

Maximum Market Penetration (MMP) Curve as a function of device payback derived from solar PV



$$\text{Net revenue per year} = \text{Avoided electric costs} - \text{incremental propane consumption costs} - \text{device O\&M}$$

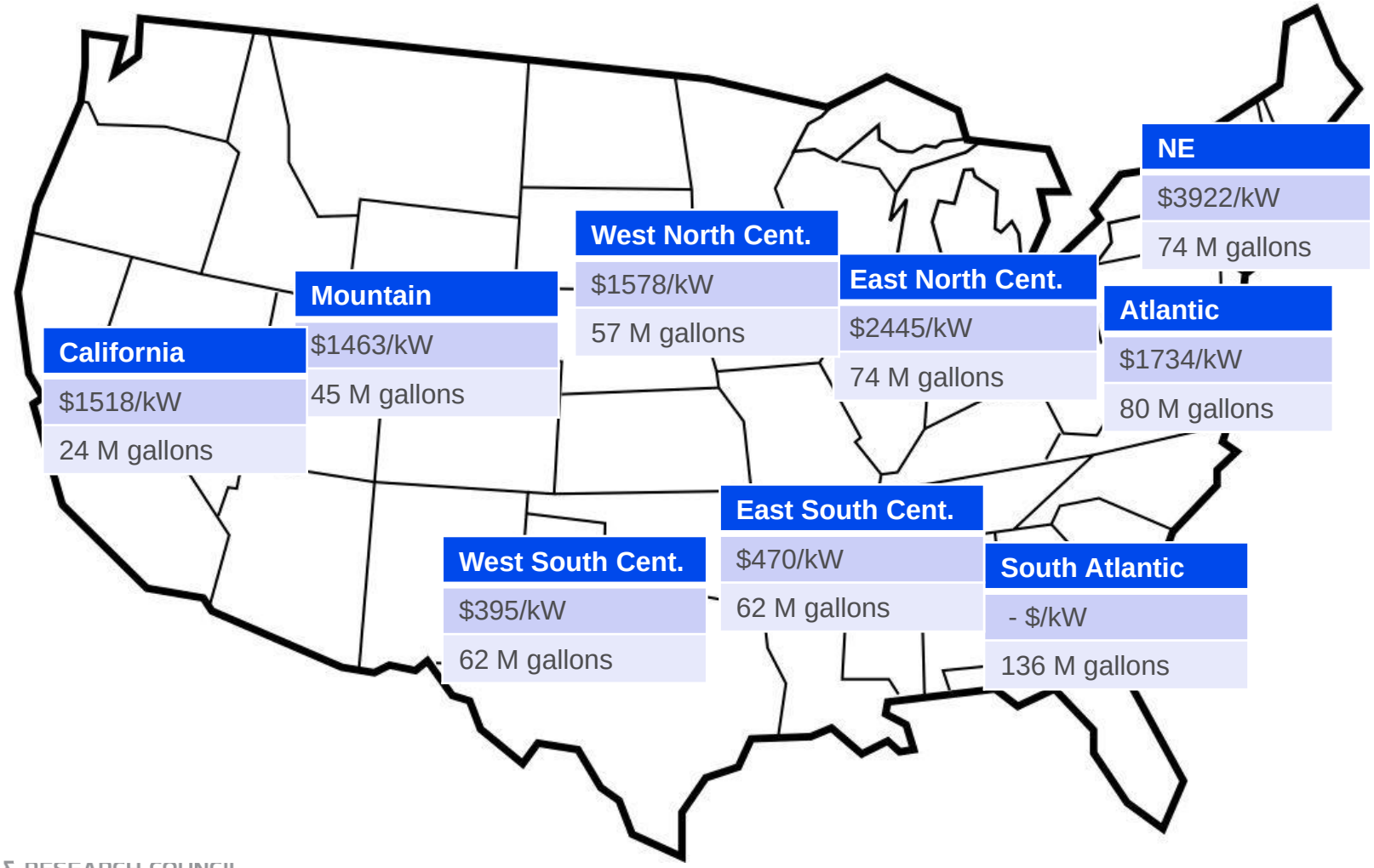
$$\textbf{Total installed system cost}\left(\frac{\$}{kW}\right) = \frac{\text{Net revenue per year} * \text{payback period}}{\text{average electrical rating of device}}$$

$$\text{Incremental propane consumption (gallons)} = (\text{propane consumption with mCHP} - \text{status quo propane consumption}) * MMP * \text{total \# of establishments in that zone}$$

Note: Model assumes all heat is used at site and grid electricity is either displaced and/or device generated electricity is net-metered at local retail price. Did not account for blackstarting, islanding, departing load charges, incentives, resiliency costs plus other embedded soft costs

Governing Metrics - Residential mCHP for a simple payback of 10 years & ~4 kW average heating load

No propane price data for PADD5 in EIA



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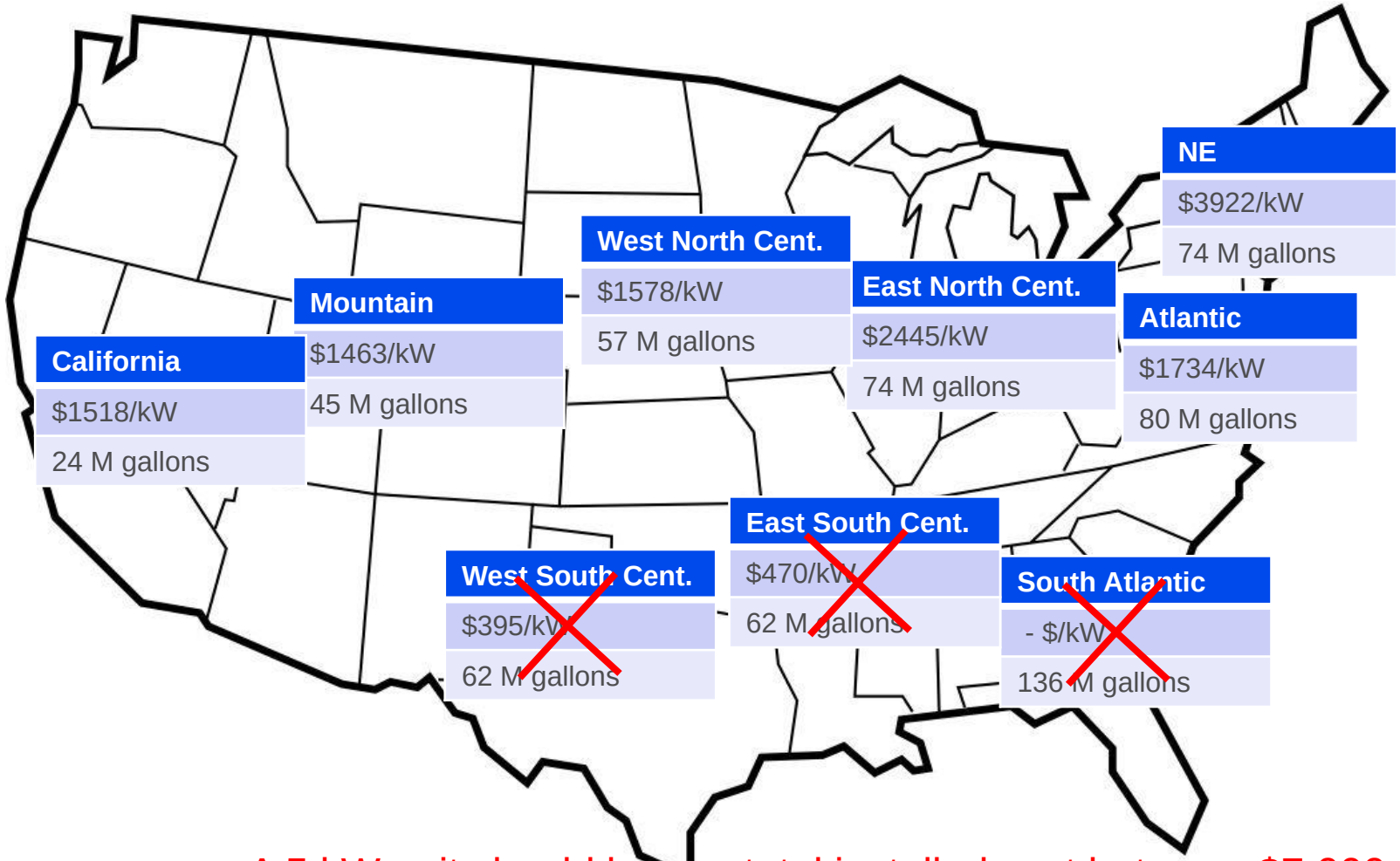
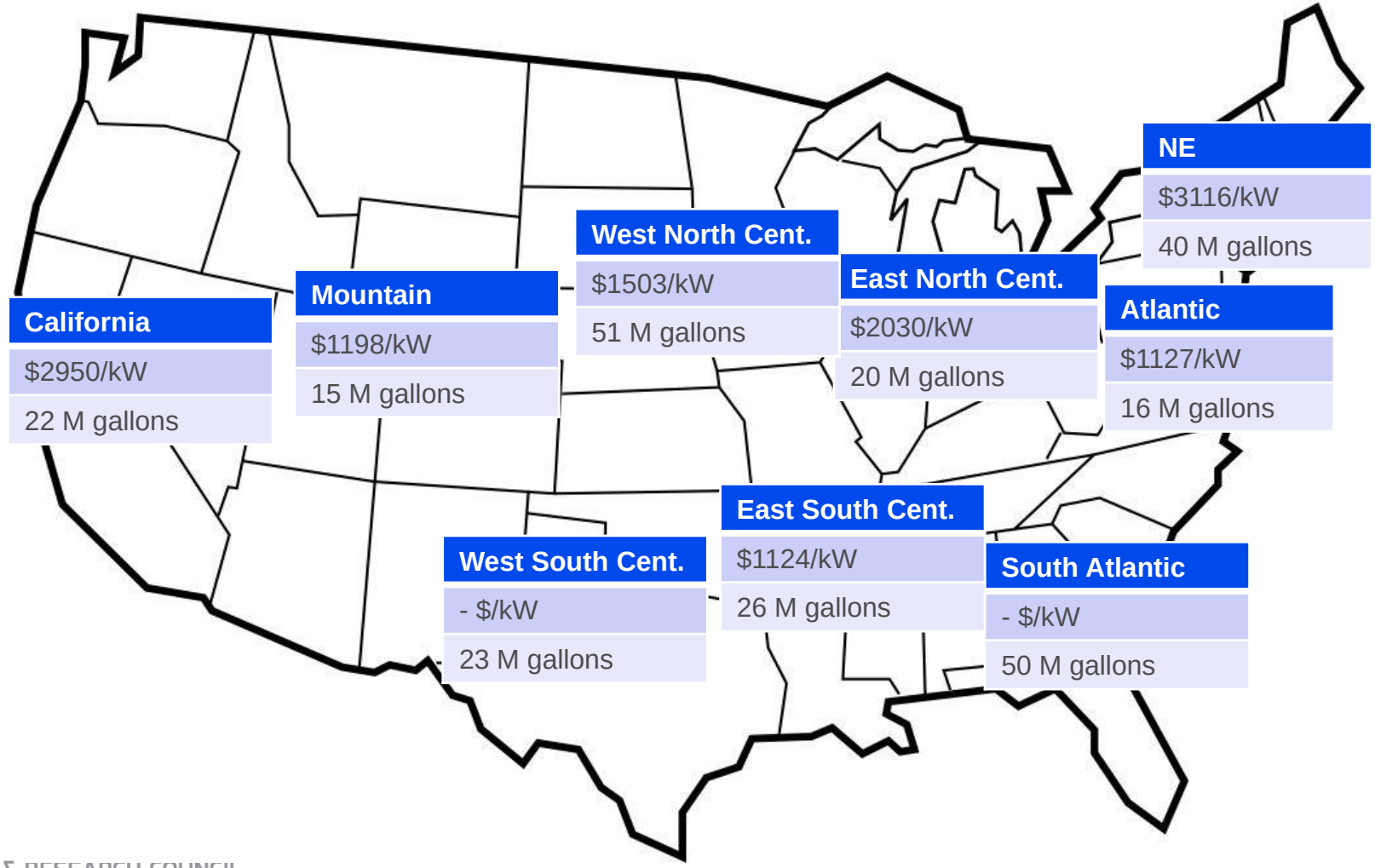


A 5 kW unit should have a total installed cost between $7,000 (Mountain) and $20,000 (NE)

Governing Metrics - Commercial mCHP for a simple payback of 10 years & ~20 kW average heating load

No propane price data for PADD5 in EIA



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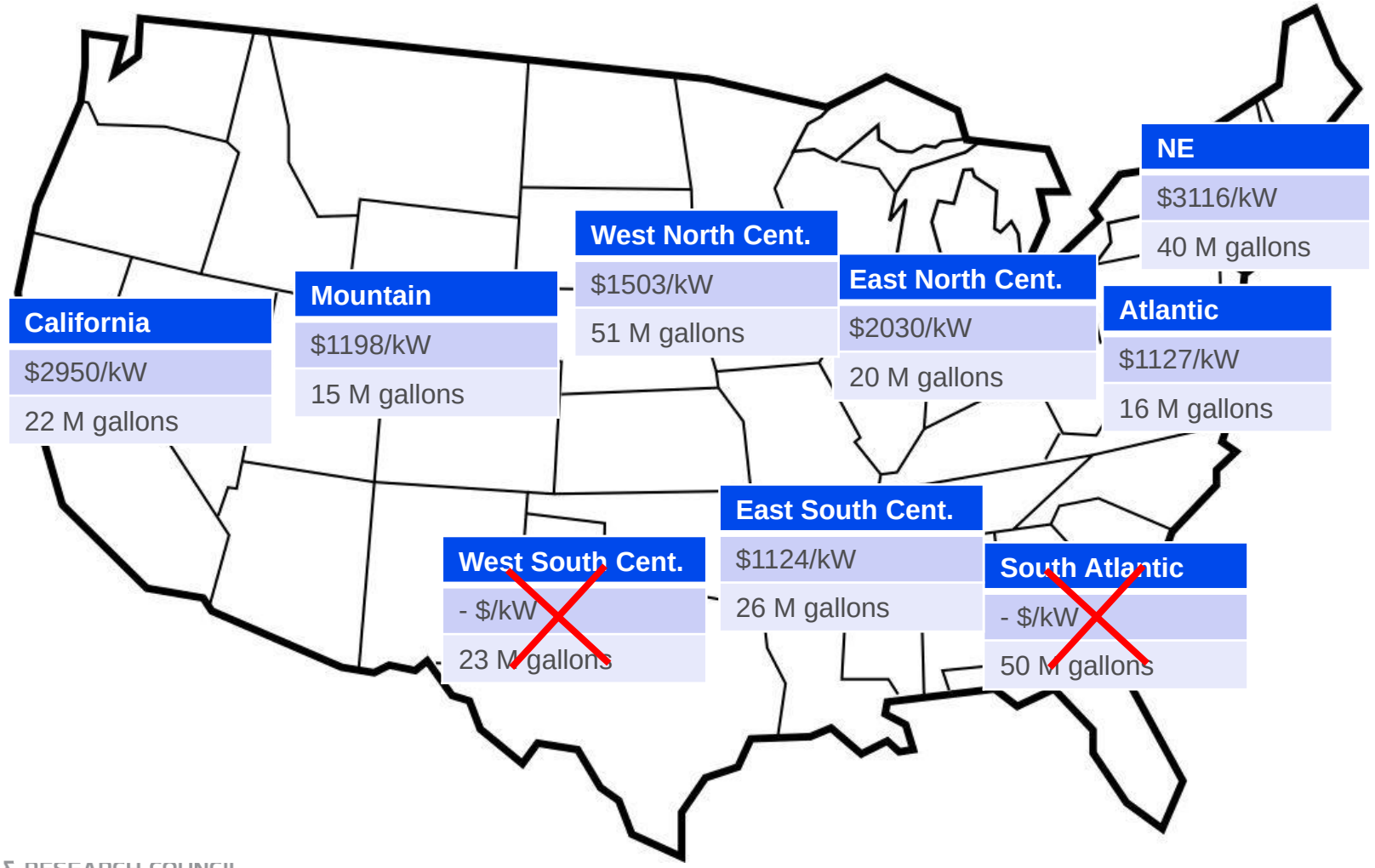
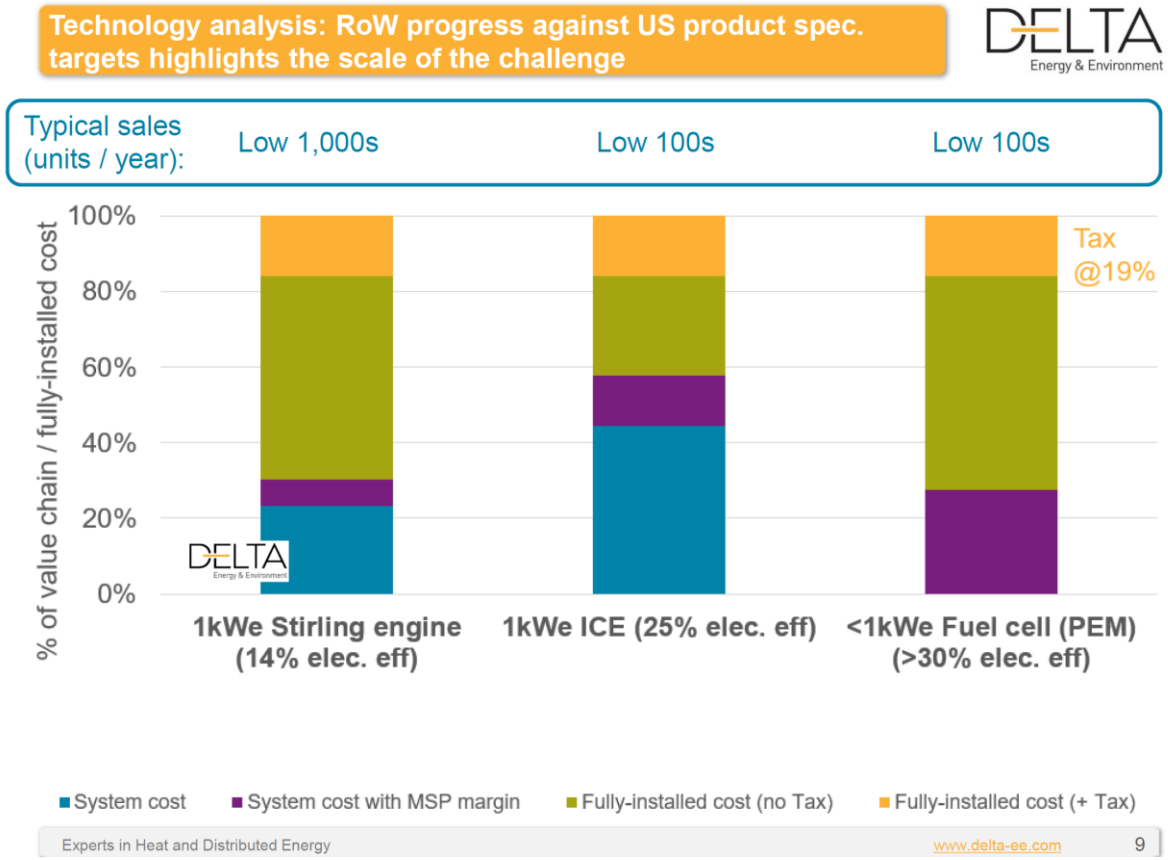


A 25 kW unit should have a total installed cost between $28,000 (South) and $78,000 (NE)

Importance of Total Installed Cost

- Total installed cost could be as high as the product cost or even higher than the product cost
- Ultimately, customer cares about the total installed cost
- Payback analysis should take into account total installed cost and NOT the product cost



Source: S. Ashurst, DeltaEE, ARPA-E GENSETS Annual Review, 2016

Low Carbon Firm Dispatchable Resource

- CHP (residential and commercial) and microgrids are emerging opportunities for propane technologies
- CHP provides both power and heat while providing partial or complete independence from the grid (off-grid)
- Diesel displacements are opportunities for propane in microgrids
- Example shown is the Truckee Microgrid in Sagehen, CA (Credit: Generac)

As per Generac case study, "*Liberty Utilities, a regulated utility with about 50,000 customers on the west side of Lake Tahoe, wanted to make upgrades, such as installing covered conductors to its transmission lines that run through a mountainous area to a remote research station operated by University of California, Berkeley. However, after running a cost and feasibility analysis, it realized it would be better to de-energize the line during wildfire season and instead utilize a containerized solar + storage system. That is when the utility company selected BoxPower, an expert in modular microgrid solutions, from a competitive bid process.*"

Credit of image and quoted text: Generac

PG&E 2021 Wildfire Safety Plan

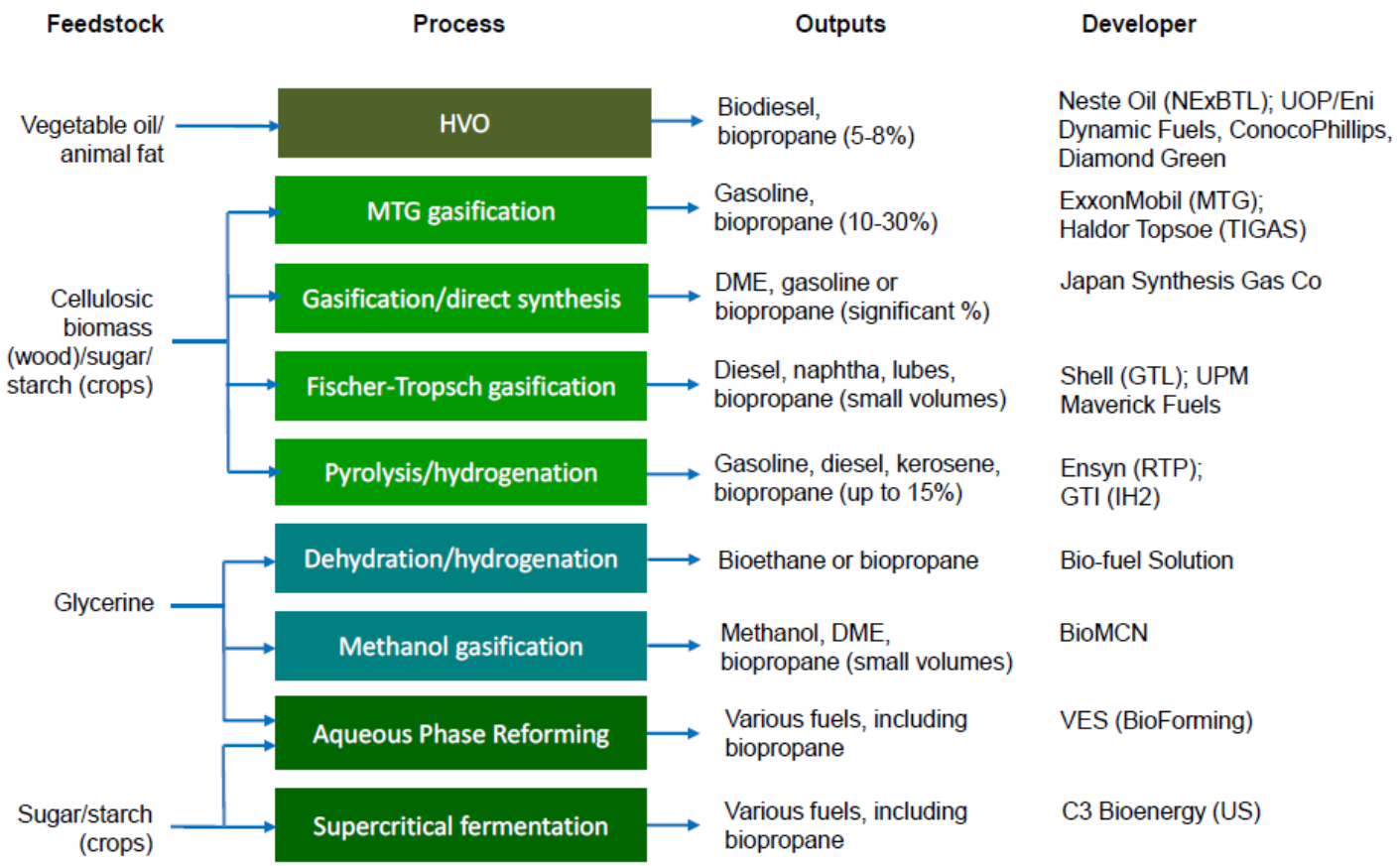
Page 319 of PG&E safety plan states: "PG&E identified the technology combination of Solar Photovoltaic Generation and Battery Energy Storage with supplemental Propane Generators as the most cost effective, reliable, and cleanest solution for initial Remote Grid sites. - PG&E found there was sufficient initial vendor interest and availability to engage in contracting to deploy systems with specifications and terms responsive to PG&E's requirements"

Source: https://www.pge.com/pge_global/common/pdfs/safety/emergency-preparedness/natural-disaster/wildfires/wildfire-mitigation-plan/2021-Wildfire-Safety-Plan.pdf

Renewable Propane and Blends

Renewable Propane will Play a Critical Role

- Renewable propane is a byproduct of renewable diesel and sustainable aviation fuel
- Predominantly sourced by Hydrotreated Vegetable Oil (HVO) process
- Carbon neutrality can be enabled by low carbon intensity fuels such as renewable propane, renewable dimethyl ether (DME) and their blends



Source: Menecon Consulting/Atlantic Consulting

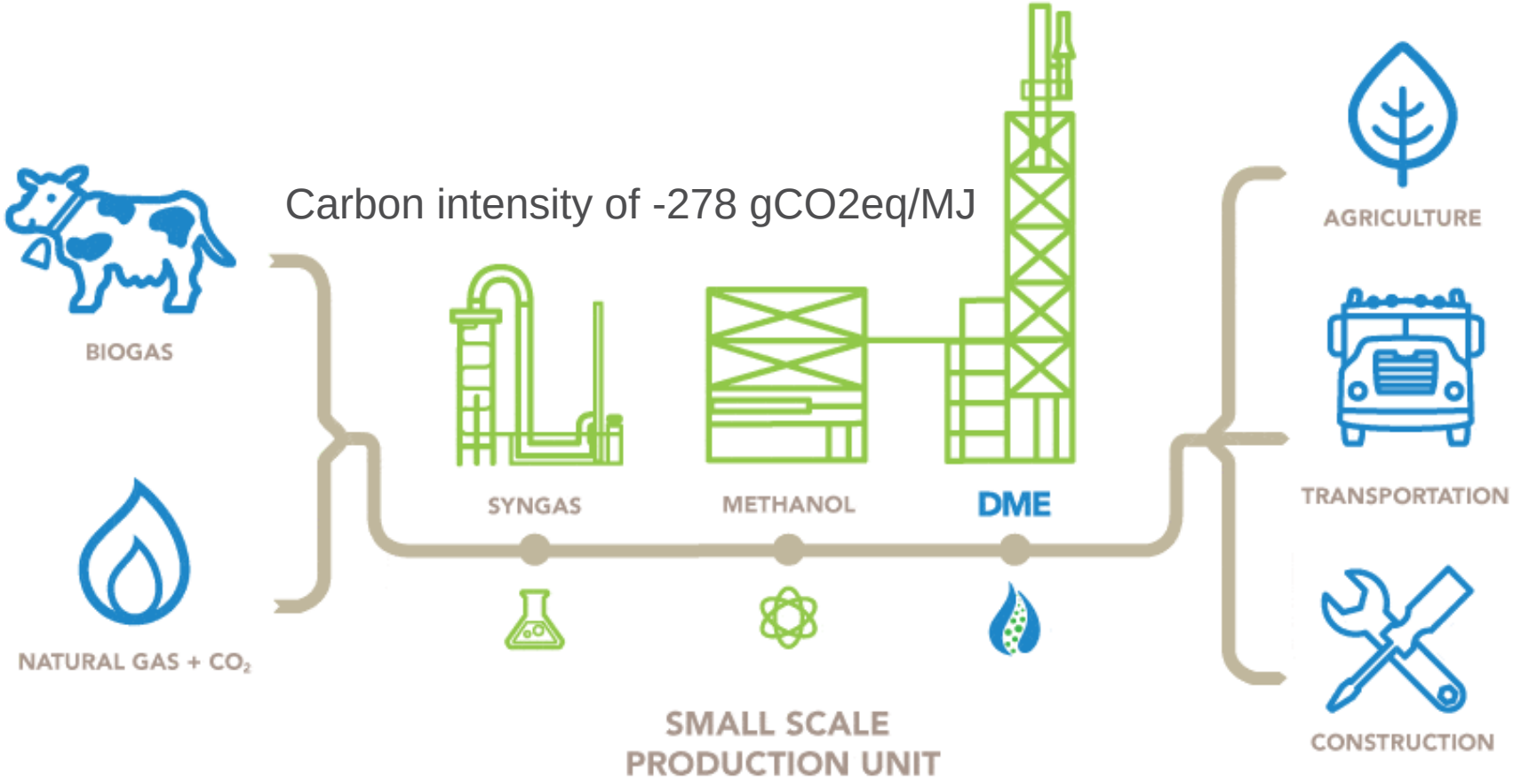
Renewable Propane

Global Volume Potential (million ton/yr)

Feedstock	2020	2030	2040	2050	Process Path
Cellulosics	0	94	101	108	Adv. chemical processes
Mixed waste	0	15	15	15	Adv. chemical processes
Bio-oils	0.2	3.3	4.2	5.2	Hydrotreating
Sugar	<0.1	0.15	0.15	0.15	Fermentation
Total RLPG	0.2	113	120	128	
% LPG Demand	0.06%	36%	38%	41%	

Renewable DME

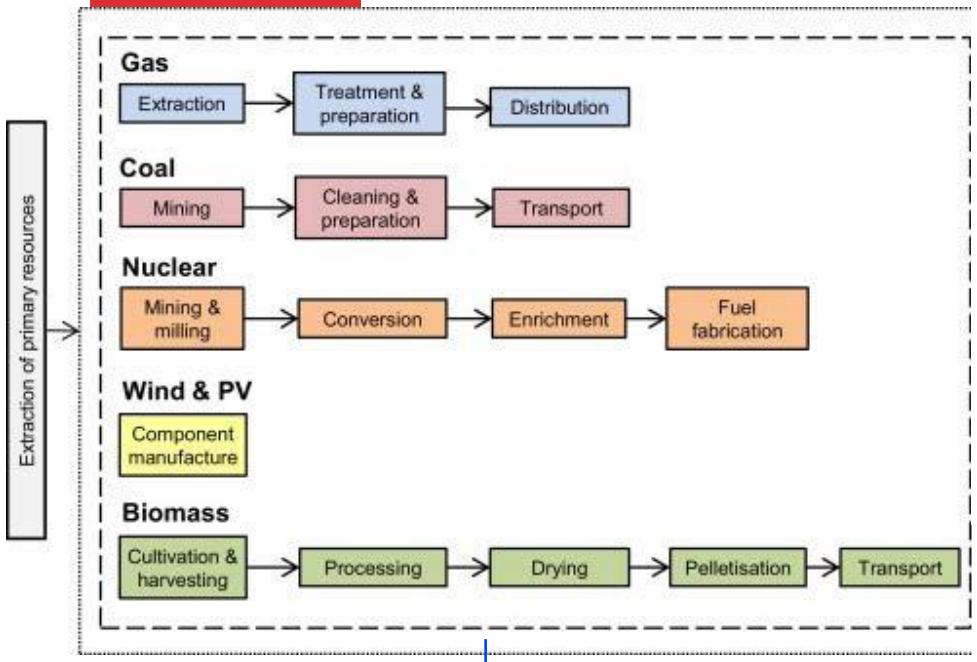
Carbon intensity of -278 gCO2eq/MJ

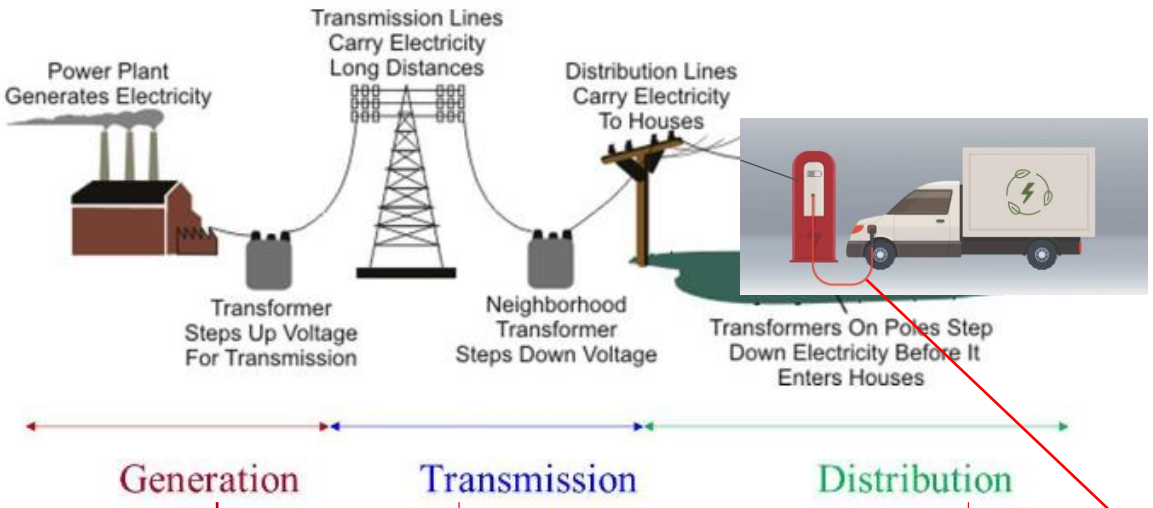


Source: Oberon Fuels

Medium-Duty Propane vs. Electric Vehicles

Example of the National Average Carbon Footprint for EVs





~10% CO2eq emissions

15.2 g/MJ

~75.5% CO2eq emissions

116.5 g/MJ

~4.5% CO2eq emissions

7 g/MJ

~10% CO2eq emissions

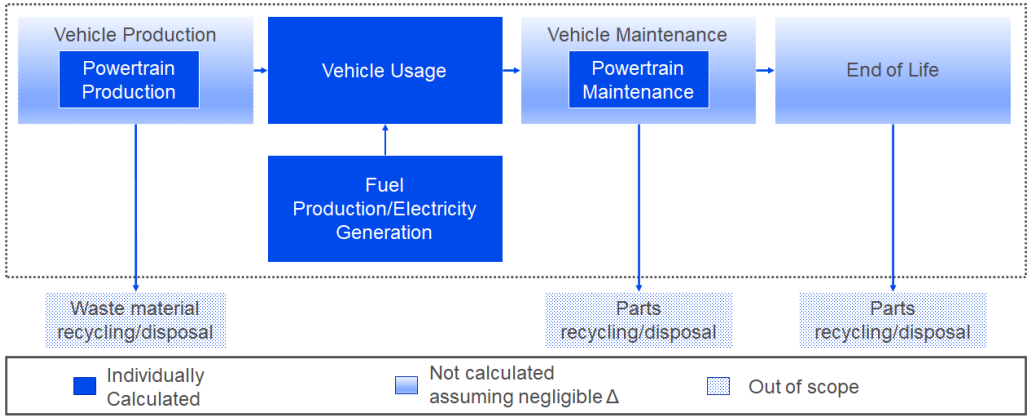
15.4 g/MJ

154.1 g/MJ – Well to tank (delivered AC power) emissions of electricity in EV

Delivered DC power to the battery will incur an additional penalty

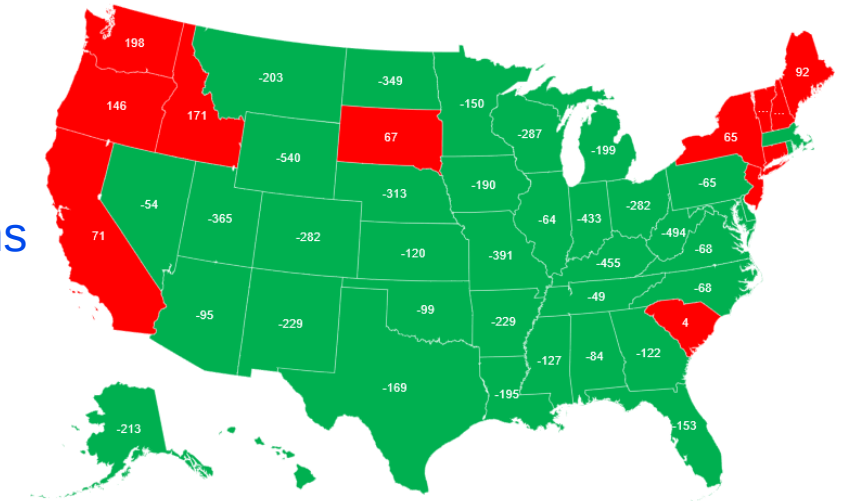
Detailed description with references can be found here: https://www.linkedin.com/pulse/greenhouse-gas-intensity-electricity-battery-electric-vishwanathan/?trackingId=AdpObqERTQGD7R2GhqAOCg%3D%3D

Propane and Blends Offer a Low Carbon Solution for MDV/HDV on a Life Cycle Basis

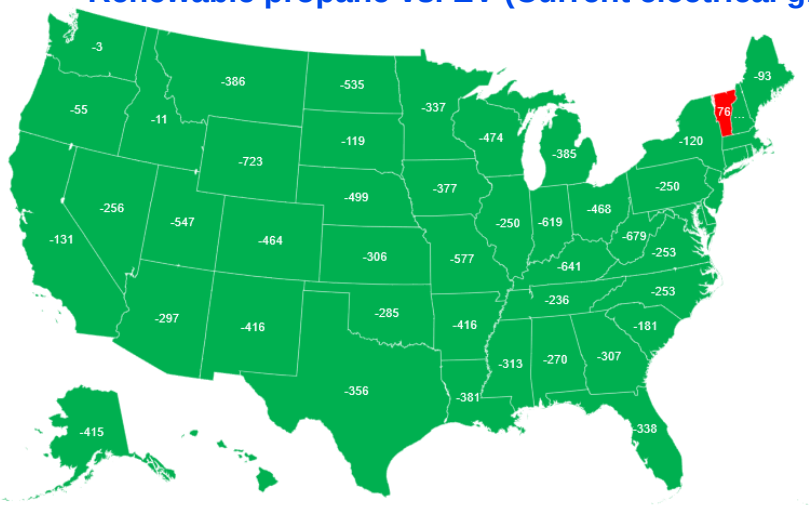


Numbers represent ΔLC CO_2 emissions in US tons per MD vehicle

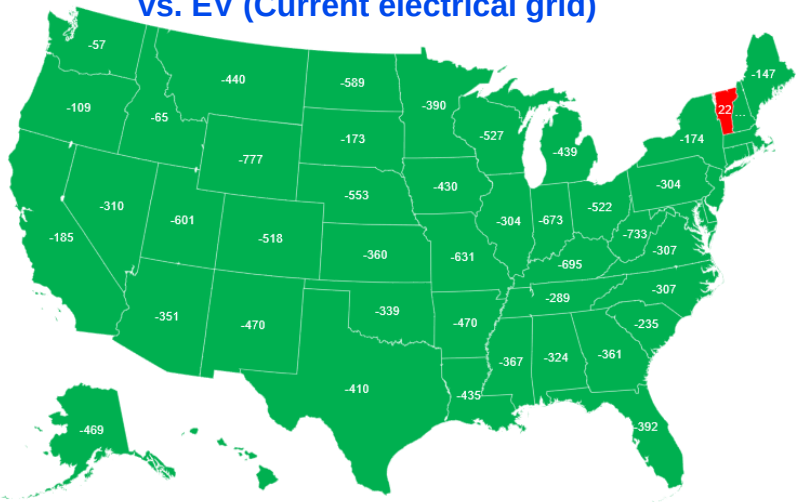
Propane vs. EV (Current electrical grid)



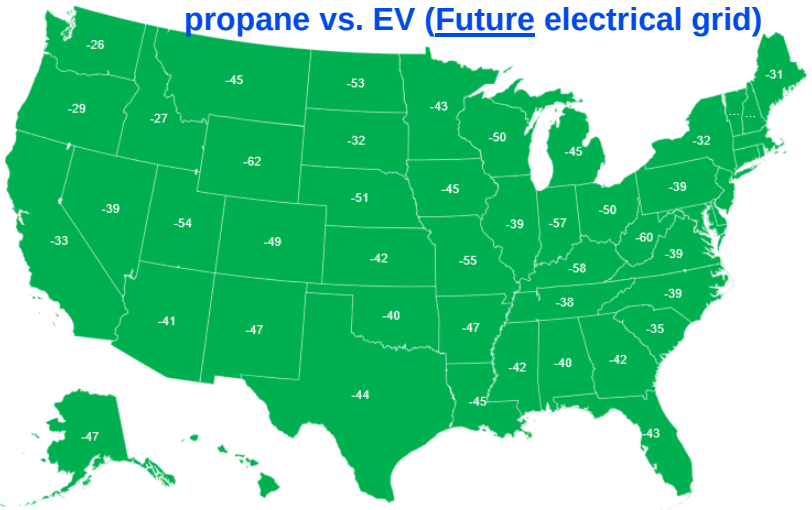
Renewable propane vs. EV (Current electrical grid)



Blended renewable DME/propane vs. EV (Current electrical grid)



Blended renewable DME/renewable propane vs. EV (Future electrical grid)



Source: Internal PERC analysis. Source: https://propane.com/research-development/emissions/decarbonization-of-md-hd-vehicles-with-propane/

Range Extender Development

- Small LPG engine powering the batteries for range extension or acting as backup source when charge is depleted
- Optimize the performance and emissions only at a suite of steady-state points vs. traditional transient calibration
- Maximize efficiency, minimize emissions and solve the range problem
- Good intersection of power generation and transportation

Source: WLPGA LPG Hybrids Report

3.5.1.1.3.3 Trucks

Project 1: Calor Gas to develop world's first hybrid LPG Range-Extended Electric 16te Cylinder truck

Calor Gas has revealed it has received funding from the UK government to develop the world's first hybrid LPG truck. Working with Magnomatics Limited, Calor will convert two of its 18t LPG tankers to hybrid drive technology, coupled with a Kinetic Energy Recovery System (KERS) which is commonly used in Formula One cars.
Calor have partnered with the Dutch EV truck specialists Emoss. Emoss have been working in this space for over 15 years and it was the development of their LPG range extended. Their investment in the development of their battery technology is really impressive and was another reason why Calor decided to work with Emoss.

The aim is to achieve significant fuel economy and an associated reduction in vehicle emissions.
Previous tests have shown a calculated fuel saving of up to 30%.
The total project cost is £1.92m of which the UK Government is providing £1.26m. For its part Calor will be receiving £111,750 of funding which represents 50% of its costs incurred in relation to the project.

The truck will have the capability to go 40 miles in battery only mode, but the LPG extender will increase the range by a further 250 miles. Making it a practical option which will be able to do a full day's work without the need to stop to recharge. The vehicle will also be geofenced, using the truck's own telematics, so we can guarantee that it will run in zero emission mode in specified zones or within our filling plants.
It will be cleaner and quieter than existing cylinder trucks, but it's the potential carbon savings that are really impressive.

Challenges	Opportunities
High efficiency at a smaller engine size. Need compression ignition?	Excellent opportunity to maximize efficiency and minimize emissions in a transportation application. Can be easily translated to power generation

Conclusions

- In short, several research and development opportunities including fundamental early-stage, applied R&D (with a path to commercialization) exist for propane/LPG and renewable propane
- Critical need to think beyond just conventional applications of propane use
- We need to consider these challenges as opportunities as propane provides a clean alternative energy solution and NOT just an opportunity as a bridge fuel

Thank you

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