CleanPeak Power-to-Gas Storage
California's Gas Grid as a Daily & Seasonal Renewable Electricity Storage Asset

Capturing Excess Daytime Renewable Electricity Stored
as Renewable Natural Gas for Nighttime Peak Power and Electric Vehicle Charging

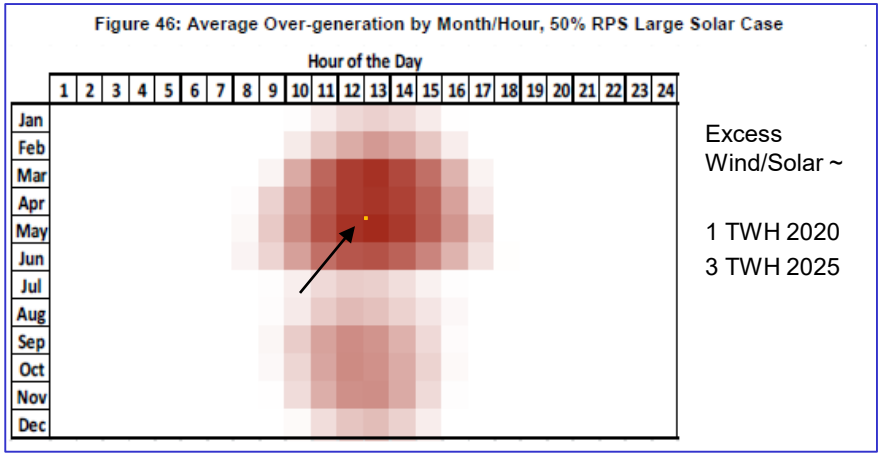
Excess Renewables + Flare Gas/CO2 = Renewable Gas for CleanPeak Power & Vehicles

California's Oversupply Is Not Sustainable*

Solar & Wind Facilities Cause Frequent Periods of Oversupply

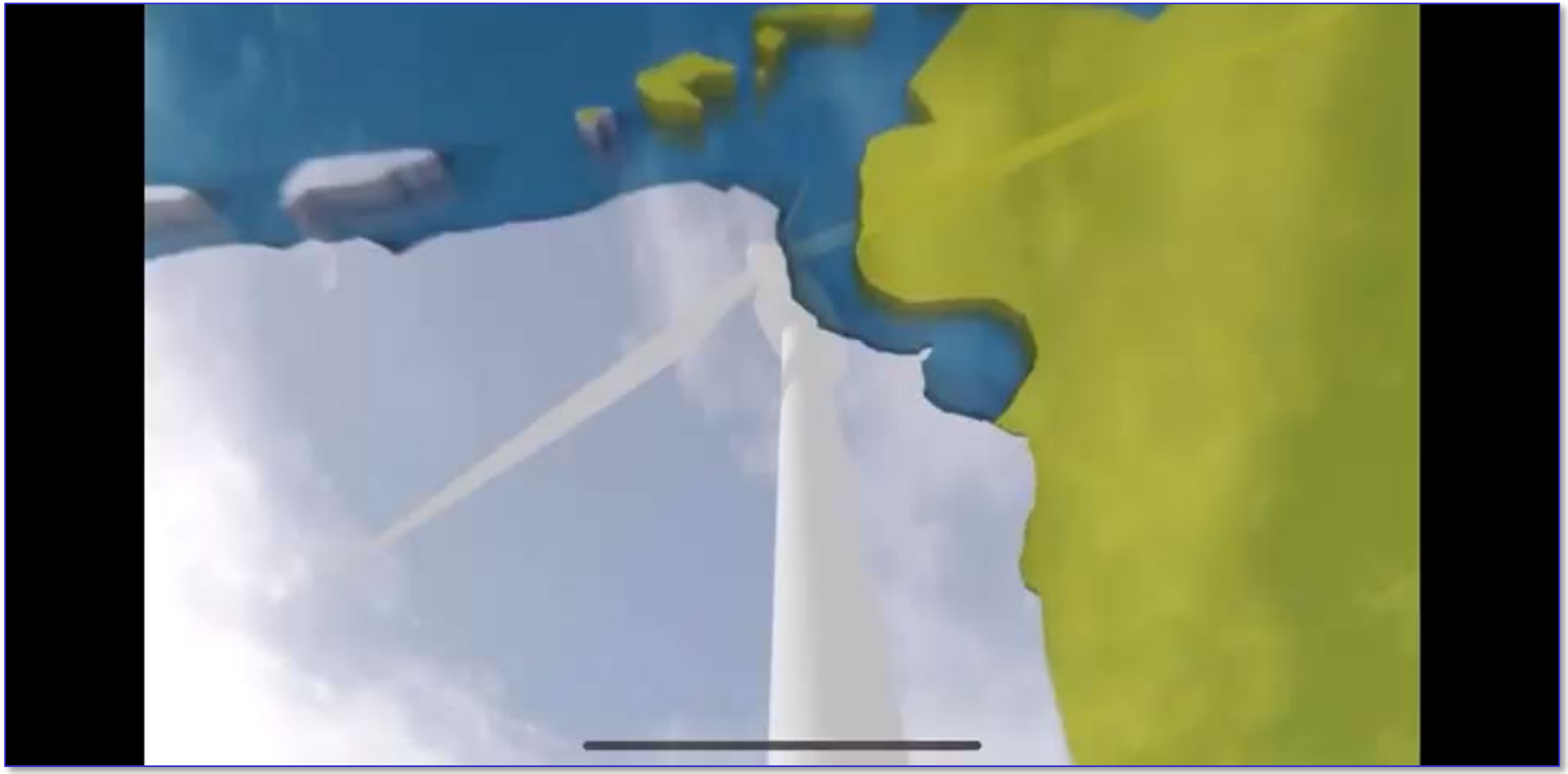
- Californians **pay** neighboring states to take excess renewable electricity, about 10% of production or 1TWH in 2019 (1 million MWH)
- The more wind and solar we build, the more excess we will have (about ~30% of production by 2025 or 10 TWH over the next five years).
- This is equivalent to the annual production from three Hoover Dams

***California ISO:** "During oversupply times, wholesale prices can be very low and even go negative in which generators have to pay utilities to take the energy. But the market often remedies the oversupply situation and automatically works to restore the balance between supply and demand. In almost all cases, **oversupply is a manageable condition but it is not a sustainable condition over time** — and this drives the need for proactive policies and actions to avoid the situation". http://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf



▮ = Excess Wind/Solar Stored in One CleanPeak Battery

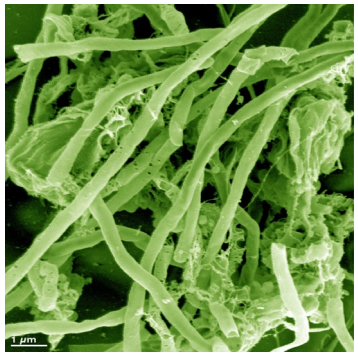
Video Clip - Power to Gas



BioCat Power to Gas

RealEnergy and its Gas Utility Partners Selected Electrochaea's BioCat Power-to-Gas System

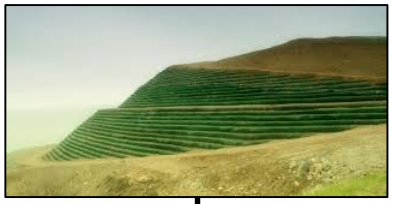
- Daytime excess renewable electricity is captured to produce hydrogen from water with an electrolyzer
- Hydrogen is blended with flared CO2 in a biologic catalyst (an Archaea) to produce renewable natural gas (RNG)
- RNG stored onsite or in gas pipelines enables CleanPeaking electricity to be discharged back to the electric grid during peak periods and evenings to charge electric vehicles - hours, weeks or months later



Methanothermobacter thermautotrophicus
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3806361/

- Southern California Edison Pathways 2045 forecasts 7.8 million electric vehicles and the California Energy Commission forecasts 15 TWH of transportation electricity grid demand by 2030
- Bulk electricity storage enables high penetrations of wind and solar
- Upgrading flared CO2 to RNG doubles all current estimates of RNG available and through sector coupling will decarbonize the electric grid, natural gas pipelines, waste and transportation sectors

CleanPeak Electricity Storage



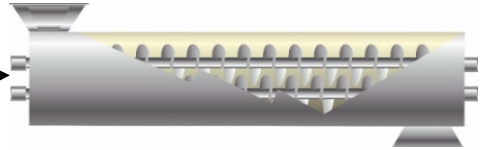
Excess Renewable Electricity, Flared CO2 and Methane Stored as Renewable Natural Gas

CleanPeak Nighttime Power – Gas Grid 'Battery' Storage Discharging

Gas Grid 'Battery' Storage Charging

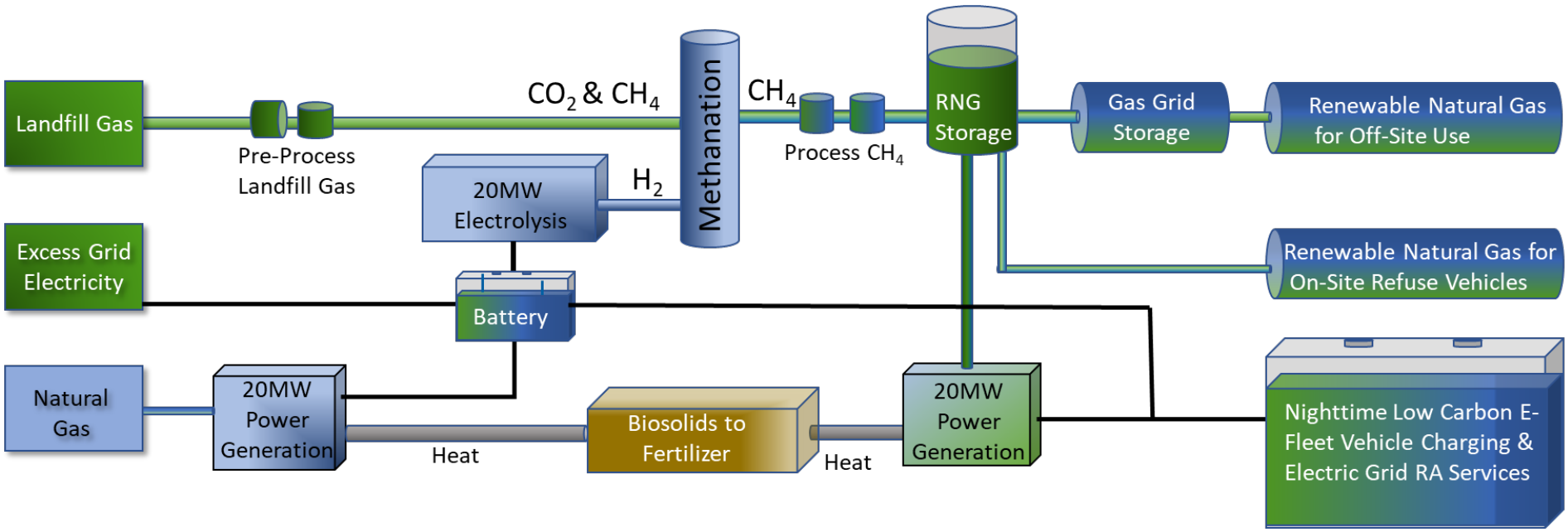
Regional Electric Vehicle Charging with Recovered Excess Renewable Electricity

Liquid CO2 Recycling



Biosolids Processing

CleanPeak Process Flow Diagram

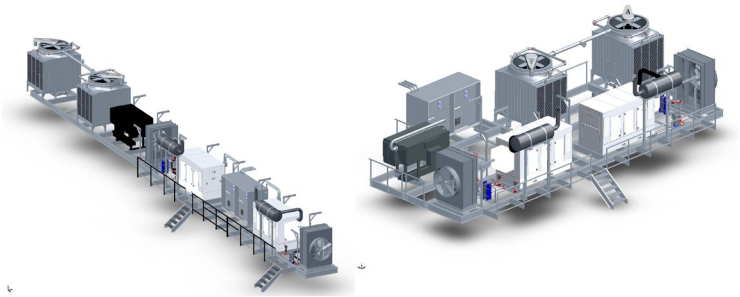


Real Development Experience

Designs, builds, owns and operates more clean onsite gas to electricity plants than any independent power producer in the United States over the last 30 years

- Executing electric and natural gas grid interconnections in several states
- Reciprocating engines, solar PV, microturbines, microgrids
- Power plant fleet sale to ArcLight/John Hancock Insurance
- Currently developing Power to Gas plant Hub and Spoke Fleets
- All systems installed under Public and Private Partnership **(P3)** Arrangements

California State Office Civic Center Plaza San Francisco, CA



RealEnergy BioGas/Natural Gas PowerPods

Bechtel Headquarters – San Francisco CA

Electrochaea – Power to Gas (Methane)

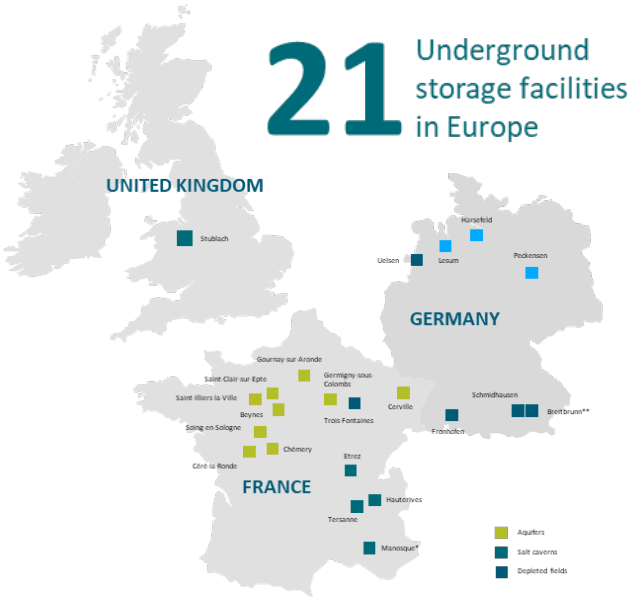
The Leading Provider of Biologic Power to Methane Technology for Carbon and Energy Storage

- The global market for energy storage is growing rapidly to decarbonize the power and transportation sectors and improve grid reliability
- Electrochaea's proprietary process technology provides a high efficiency system to convert renewable electrical power and CO_2 into methane (CH_4), for:
  - **Long-term storage and distribution of renewable energy**
  - **Production of renewable Methane and**
  - **CO_2 mitigation**

Storengy – Gas Utility Partnering

storengy
A company of ENGIE

21 Underground storage facilities in Europe



1st
Europe's leading operator of natural gas storage facilities

12.2 Bcm
Gas storage capacity

Employees
800
In France
160
In Germany
45
In the United Kingdom

4th
World's largest operator of natural gas storage facilities

0 TF
Lost time injury frequency rate

SoCalGas – Gas Utility Partnering

Southern California Gas Company and the US Department of Energy National Renewable Energy Laboratory launch the first U.S. Power-to-Gas Project with Electrochaea

This innovative technology could provide North America with a large-scale, cost-effective solution for storing excess energy produced from renewable sources.

California's Clean Energy Future

Our vision is to be the cleanest natural gas utility in North America, delivering affordable and increasingly renewable energy to our customers. Natural gas has played a role in improving air quality, particularly in electric generation as natural gas replaced coal. As the state works to achieve its climate change goals, natural gas along with renewable natural gas and hydrogen will serve as energy sources to help California advance its clean energy agenda.

Photo by Werner Slocum, NREL 4726

CleanPeak Infrastructure

Design
Finance
Permit
Build
Own
Operate

A RealEnergy Power Storage Infrastructure to Support Power to Gas

- 25 MW substation to import/store excess renewable power from the grid
- 20 MW hydrogen electrolyzer and methanizer blending H2 & CO2 (24h)
- 5 MWH Li-ion battery for instantaneous storage/dispatch integration
- 20 MW cogen power for electrolyzer when excess power is not available
- 233,000 MWH renewable natural gas produced/stored annually

- 20 MW renewable cogen for ~1,400 daily LHD truck/bus charging (12h)
- 42,800 MWH renewable gas dispensed - onsite vehicles, pipeline injection

- Hubs – Sites with 1,400 scfm minimum flared biogas, <5 miles to gas grid
- Spokes – Landfills and WWTP with no gas grid injection access
- Negative carbon fuel (including mobile and stationary reductions)
- Electric utility standby service contracts (RA) 'battery storage' (12h)

An Andritz Biosolids Processing Facility Using the P2G Waste Heat

- Pasteurizing local biosolids to EPA Class A fertilizer for beneficial reuse
- Processing 420 TPD biosolids from 22% to 92% Total Solids
- Keeping water and nutrients local (Nitrogen, Potassium, Phosphorus)
- Andritz proven paddle drying with total odor control for biosolids
- ~7,000 fewer diesel long haul truck trips to Arizona per year (350 miles)

CleanPeak Electrolyzer/Methanizer

An Electrochaea BioCat Power to Gas Plant

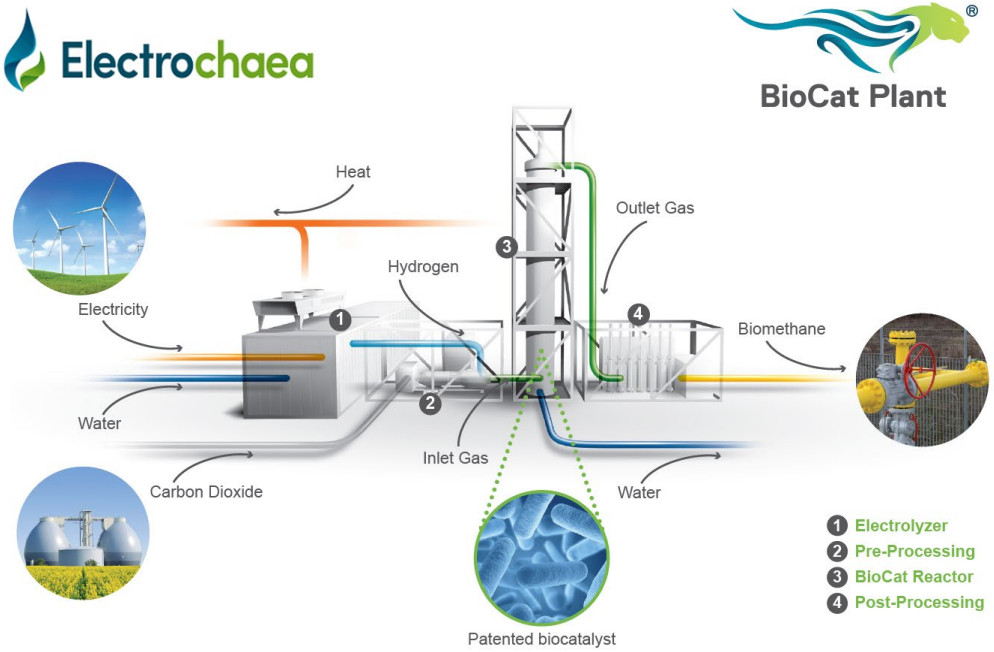
Electrochaea's bio-methanation technology efficiently produces renewable methane (natural) gas from two gases, carbon dioxide and hydrogen.

This pipeline renewable gas can be used in any natural gas application such as transportation, in place of fossil-fuel derived natural gas. The renewable natural gas (RNG) is produced in a continuously stirred vessel, the BioCat reactor, by a single-celled organism, called archaea. This organism is the biocatalyst which completes the reaction described below:

$$CO_2 + 4\,H_2 \rightarrow CH_4 + 2\,H_2O + heat$$

where CO_2 is carbon dioxide, H_2 is hydrogen, CH_4 is methane and H_2O is water.

The archaea synthesize CH4 from CO2 by replacing the oxygen with hydrogen. The substrates for the reaction are combined at a ratio of four hydrogen (H2) molecules to one molecule of carbon dioxide (CO2) to produce one molecule of methane (CH4) and two molecules of water (H2O). In the 20MW electrolyzer process, 200 MWH/D heat is also generated to pasteurize biosolids and capture CO2.



CleanPeak Vehicle Charging

Renewable Gas Cogeneration by Rolls Royce

- A highly flexible supply shifting resource (hours, days, months) ~ 12 hour utility Resource Adequacy services
- 20 MW – 240 MWH/D CleanPeak nightly electric vehicle charging (immediate ramping, N+4 reliability)
- Qualified low carbon electricity for vehicles (California Low Carbon Fuel Standard)
- 216 MWH/D heat for pasteurizing local biosolids

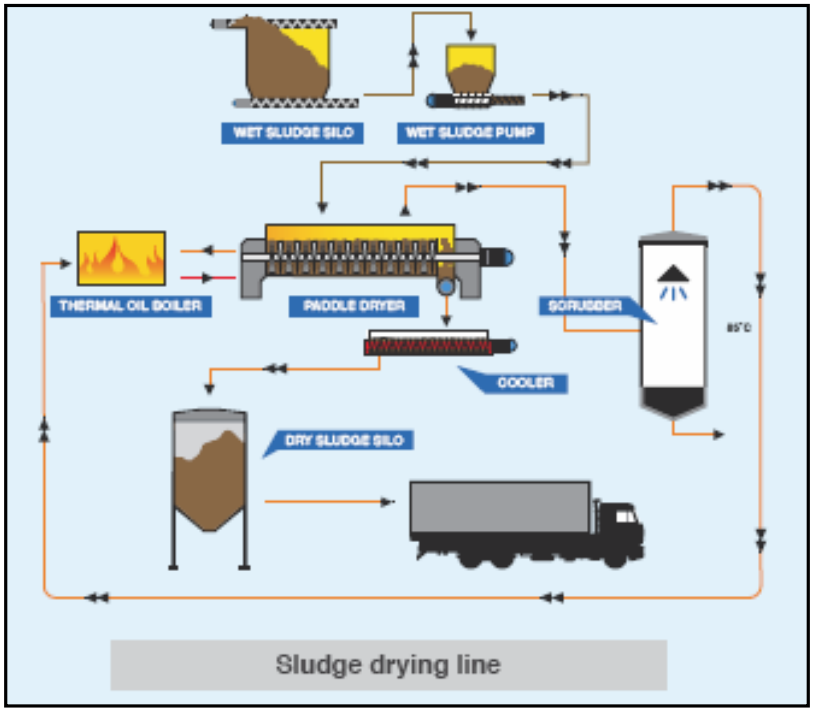
Exhaust CO2 Capture by Pentair

- World leader for CO2 purification
- Over 1,000 plants installed
- Fully automatic operation
- Sized for desired plant carbon intensity

CleanPeak Biosolids Processing

Andritz Paddle Dryers

- Andritz GPD 17W300
- 160+ years of industrial and engineering experience
- Paddle drying / processing
- Indirect (no flame) once-through drying
- Sludge temperatures of 100 ºC for pasteurization-EPA Part 503
- EPA Class A unrestricted dry fertilizer directly discharged to enclosed trailers for local beneficial reuse



Sludge drying line

California's Gas Grid - Largest Battery in the World

Electricity Storage

- **Very limited capacity**
- **Very limited storage cycles**
- **Very short duration storage**

Gas Grid Storage

- **Virtually unlimited gas grid electricity storage capacity**
- **Unlimited storage cycles**
- **Long-term duration storage**
- **Extensive distribution**

- California curtailed 1 Terawatt Hour (1 Million Megawatt Hours) of renewables in 2019
- California's 300 TWH electricity grid is not a battery and cannot store excess renewable energy
- California's 600 TWH gas grid can store 100 TWH of renewable electricity exceeding all future needs

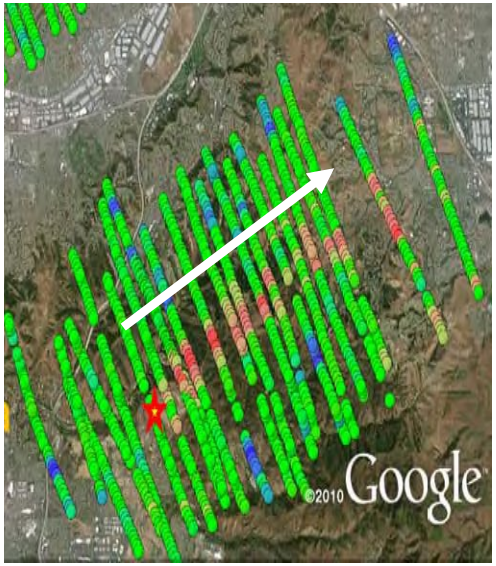
RealEnergy is seeking biogenic CO2 and flare gas to meet this renewable energy storage challenge:

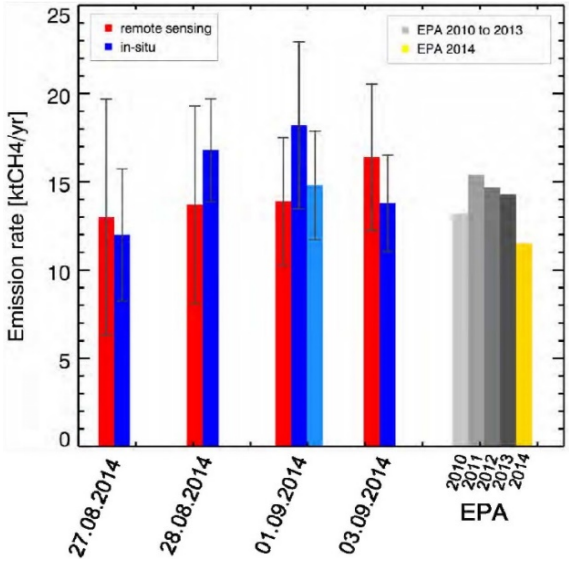
- To enable high penetrations of wind/solar developments by reducing curtailment cost/risk
- To enable regulatory agencies, CCA's and load serving entities to fulfill legislative mandates
- Doubling RNG production at landfills, wastewater treatment, ethanol plants

Biogas & CO2 - Surface Emissions Plumes

Landfill surface emission plumes may be significantly underestimated by the EPA

- New Jet Propulsion Lab airborne/satellite methane mappers focus on CH4 fluxes and plumes
- New landfill technologies may reduce surface emissions and maximize renewable biogas/CO2 capture
- An existing landfill with a 1400 scfm flare (700 scfm RNG) might realize 2800 scfm with real-time well tuning and other techniques. With a RealEnergy CleanPeak plant, all 2800 scfm becomes stored RNG

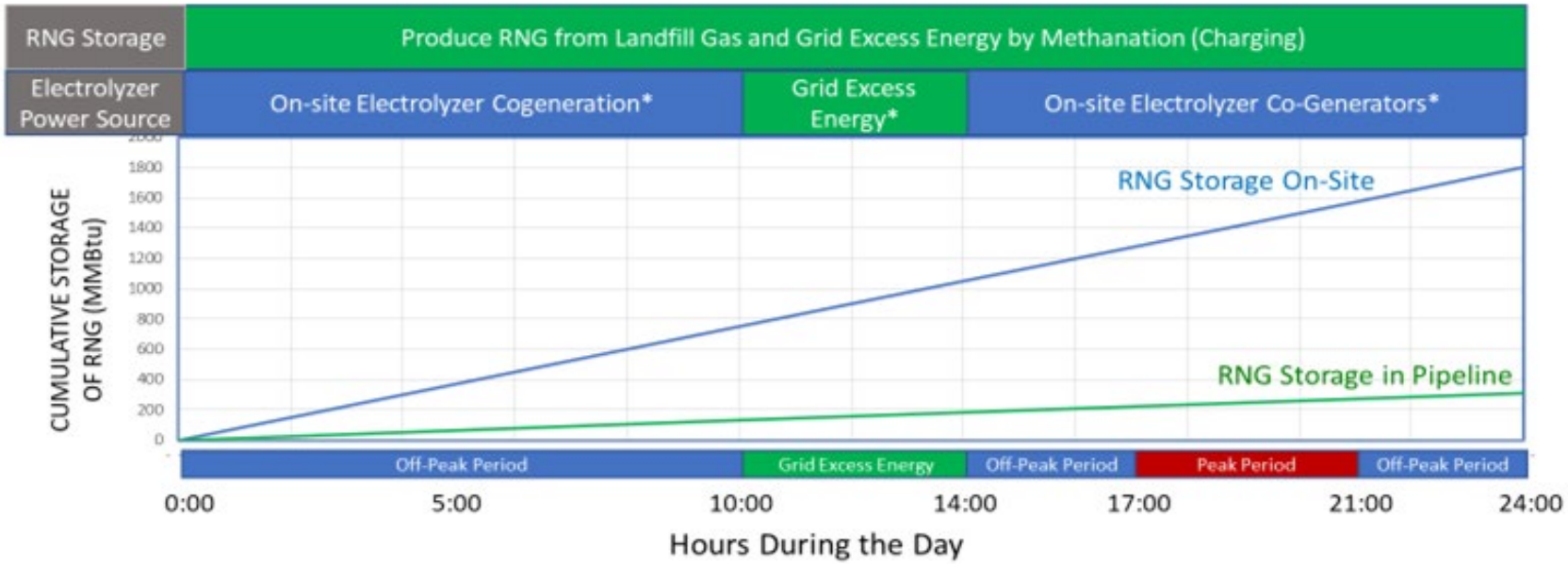




Storage of Produced RNG (Charging)

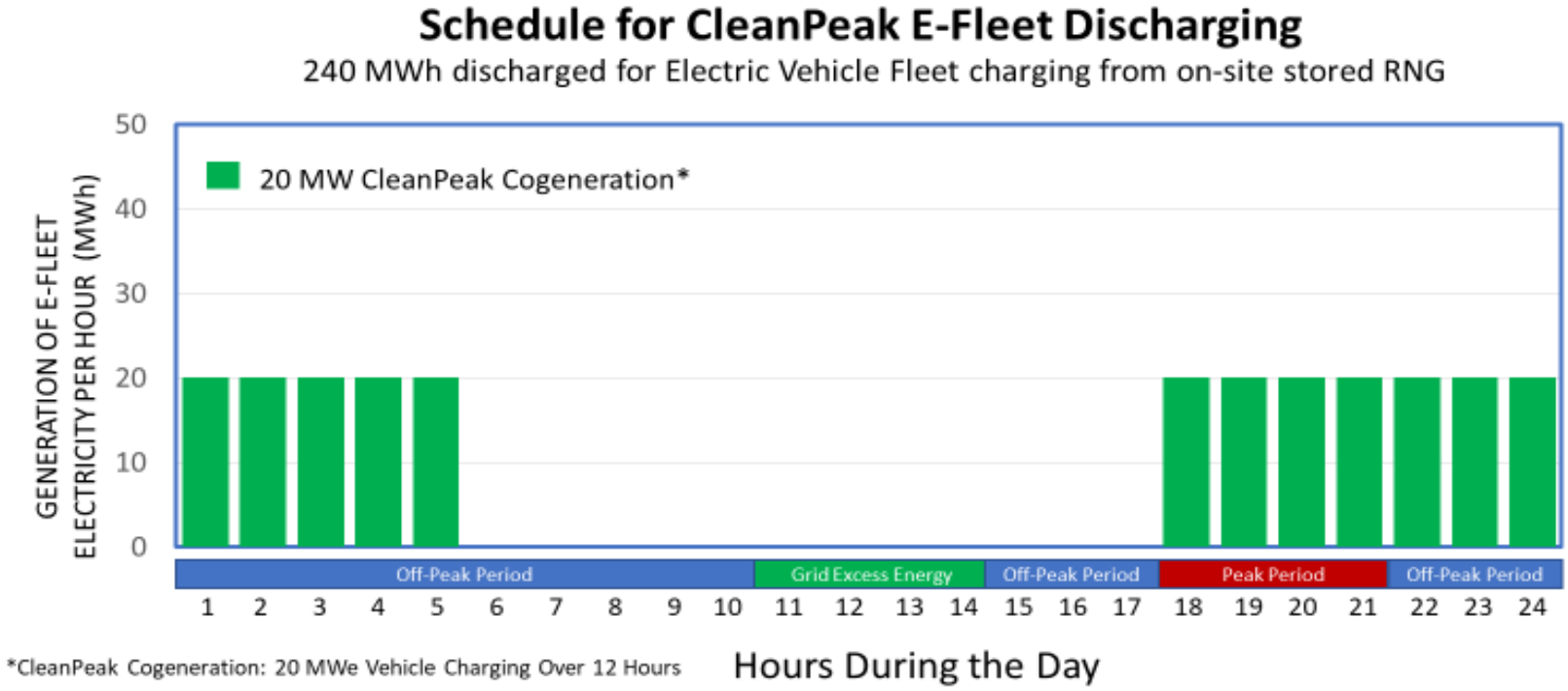
Schedule for CleanPeak Renewable Natural Gas Storage (Charging)

On-Site and Pipeline Storage – A Battery for Nighttime Renewable Remote E-Fleet Vehicle Charging

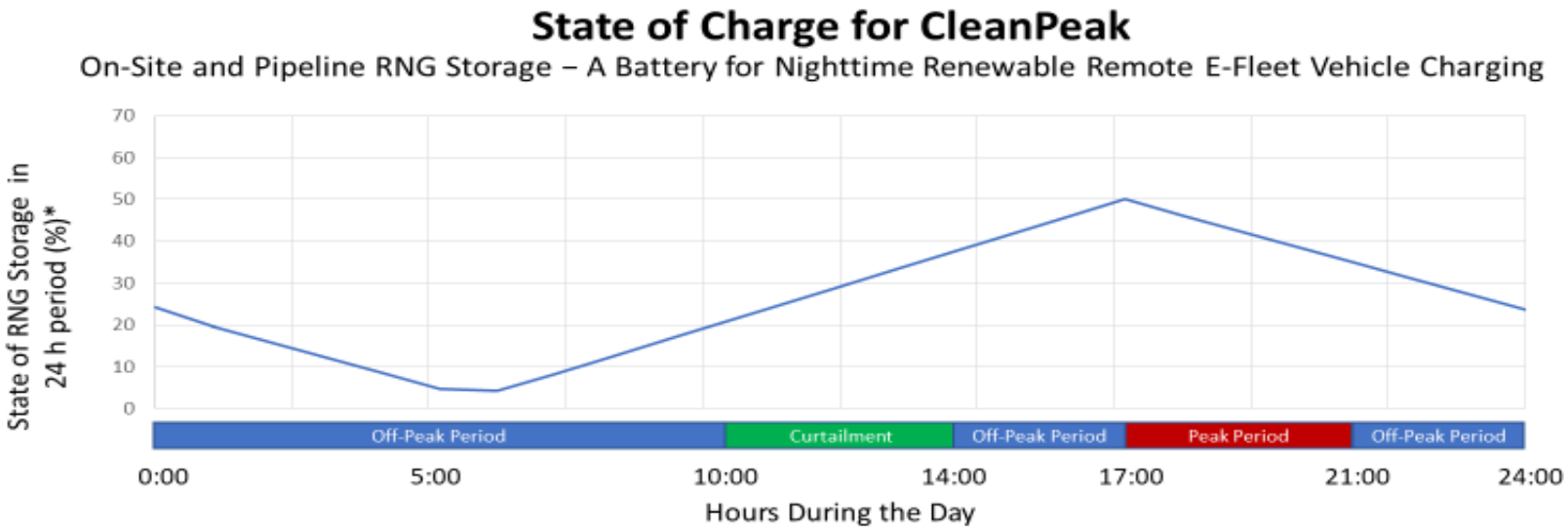


*Electrolyzer Cogeneration and Imported Grid Excess Energy: 20 MWe Over 24 Hours

Use of Stored RNG (Discharging)

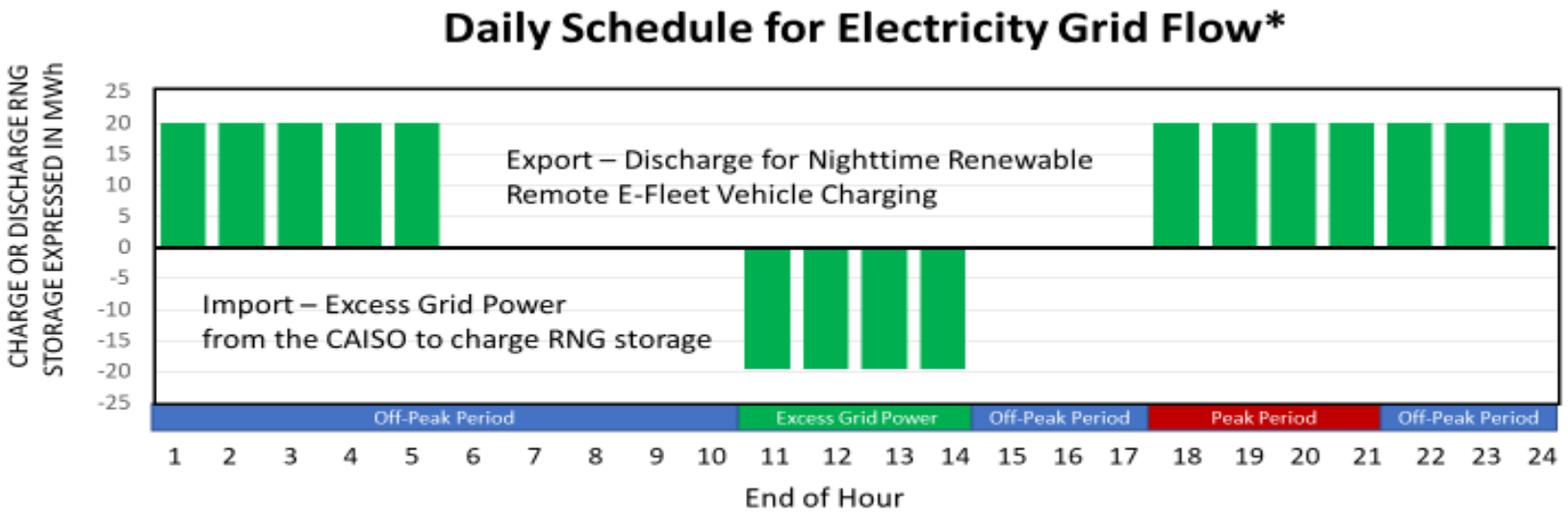


State of Charge (RNG in Storage)



*Storage calculation based on 2,100 MMBtu RNG produced during a 24 hour period

CleanPeak Electrical Grid Flows



*NOTE: All imported and exported grid power shown.

For More Information

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Headquarters
San Francisco,
California
1000 kW System

Kevin D. Best
Chief Executive Officer
RealEnergy
1500 Soscol Ferry Road
Napa, California 94558

Phone: 707 944 2400 x109
Cellular: 707 426 3300

kbest@realenergy.com
www.realenergy.com

Primary Onsite Power ~ MicroGrids ~ Carbon Negative

Appendix

California needs 80,000 MW of new clean generation and 30,000 MW of energy storage over the next 25 years.

Energy storage will be essential because the most cost effective, carbon free generation sources – wind and solar – are intermittent.

Southern California Edison Pathway 2045

RealEnergy is developing a California fleet of scalable storage and sector coupling infrastructure to absorb bulk surplus electricity from renewables and feed that electricity back to the grid on demand hours, days or months later.

RealEnergy – US Biogas 2019

RealEnergy P3 Developments

Tishman Speyer
San Francisco, CA

Trammell Crow
Torrance, CA

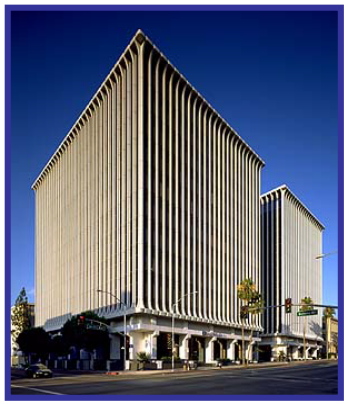
Bechtel
San Francisco,
CA

Transwestern
So. California and New Jersey

RealEnergy P3 Developments

State of California
Public Utilities
Commission,
San Francisco

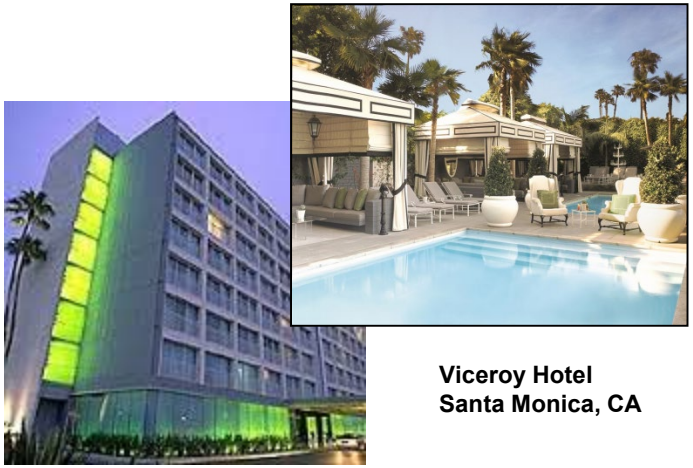
California State Office
Building, Oakland, CA



GE/Arden
Beverly Hills, CA

KOR, Marina Del Rey, CA

Marriott Hotel
Walton/SCS Advisors,
Fremont, CA



Viceroy Hotel
Santa Monica, CA

RealEnergy P3 Developments

Ensemble, Long Beach, CA

Wareham Development, Emeryville, CA

RREEF, Carlsbad, CA

CommonWealth Partners
San Diego, CA

GE/Arden
Beverly Hills, CA

GE/Arden, Long Beach, CA

RealSustainability

Design, Finance, Permit, Build, Own & Operate

- Designed as envisioned by waste/energy regulatory agencies
- Privately financed, for-profit facilities, funding the technology
- Delivering infrastructure & stable financial returns to pension/insurance funds

Economic Sustainability with P3 (Public and Private Partnerships)

- No up front capital/risk requirements w/land lease
- Reducing energy costs and greenhouse gas through royalties
- Strategic planning through intensive, inclusive team design charrettes

Sustainability…

Economic
Environmental
Social
Energy
Food
Agriculture



RealEnergy Biogas Design Charrette Napa Valley – Clos Pegase Winery

Development Team

SternBrothers&Co.

JH JONES HALL

Developer - Managing Member	RealEnergy
Developer - Structured Transactions	EN-RGY Concepts
California General Contractor	ACCO Engineered Systems
Architectural - Design	JRMA
Environmental Planning and Permitting	Montrose Environmental
Controls Engineer	By Project
Civil/Structural/Electrical Engineer	SLR International
Placement Agent Debt	Stern Brothers
Corporate Counsel	Clean Energy Counsel
Tax Counsel	Jones Hall
Placement Agent Counsel	Orrick
CPA	Pricewaterhouse Coopers
Trustee	US Bank
Potential Incentives	SoCalGas
	California Air Resources Board
	California Energy Commission
	SCAQMD
	Southern California Edison

Power to Gas Fast Facts

RealEnergy CleanPeak Power to Gas Plants
Storing 10 TWH of Surplus Renewable Electricity in the Public Gas Grid as Renewable Natural Gas

As new solar and wind facilities add to our renewable energy supplies, periods of oversupply become more common. Power to gas plants can store this surplus renewable electricity as renewable hydrogen or renewable natural gas injected directly into the public gas grid for later use; hours, days or months later as a CleanPeak renewable natural gas fuel for local peaking plants. Renewable electricity stored as renewable natural gas can charge electric vehicles, fuel CNG vehicles or flow to core gas customers to decarbonize their use of natural gas. Power to gas facilities:

- Enable renewable asset owners to reduce their cost of curtailment – paying to dispose of surplus electricity
- Enable renewable asset developers to manage their risk of curtailment costs
- Enable regulatory agencies to fulfill their legislative mandates at the lowest cost
- Decarbonize local natural gas peaking plants, vehicle fleets, gas users and the gas grid
- Double renewable natural gas production from landfills, wastewater treatment and ethanol plants

Approximately 100 distributed power to gas 20MW gas grid storage plants developed throughout the State of California could repurpose curtailed renewable electricity, flared methane and biogenic CO2, further decarbonizing the public gas grid. If 10 Terawatt hours (TWH) renewable electricity avoids shut down/curtailment over 5 years, over 4 million mTCO2 reductions could be realized.

California Fast Facts

Peak Electricity Demand	50,000 MW	.05 TW	**The historic peak in California occurred on July 24, 2006 (50,270 MW)** https://www.caiso.com/Documents/CaliforniaISOPeakLoadHistory.pdf
Average Electricity Demand	30,000MW	.03 TW	https://www.eia.gov/electricity/state/california/ 265,000,000 MWH / 8,760 hours per year
Electricity Generation (Yearly)	300,000,000 MWH	300 TWH	https://ww2.energy.ca.gov/almanac/electricity_data/total_system_power.html
Wind and Solar Electricity Production (2018)	65,000,000 MWH	65 TWH	**The electric grid source mix includes almost 23% non-dispatchable wind and solar** https://ww2.energy.ca.gov/almanac/electricity_data/total_system_power.html
Curtailed Renewable Electricity Oversupply (2019 estimated)	1,000,000 MWH	1 TWH	**California continues to produce an increasing oversupply of renewable energy each year and must curtail production, PAYING other states to take our surplus renewables** (As of June 26, 2019, 681,667 MWH have been curtailed. In previous years, approximately 65% of the total year's curtailment occurs in the first 6 months. A 1.05 TWH estimate for the total year's curtailment should be a reasonable estimate). http://www.caiso.com/Documents/Wind_SolarReal-TimeDispatchCurtailmentReportJun26_2019.pdf#search=curtailment%20june%2026

Estimated Curtailed Renewable Electricity Oversupply (when we reach 30% contribution from wind and solar)	3,000,000 MWH	3 TWH	**At a 30% wind and solar contribution, California will produce a greater oversupply, and we may curtail three times what we curtail today**
Emissions Reductions Over 5 Years Fueling Power Plants with CleanPeak Pipeline-Stored Curtailed Renewable Energy vs Fossil Natural Gas	10,000,000 MWH	10 TWH **4,280,000 mTCO2**	CAISO – "…the GHG emissions from unspecified imports, including EIM transfers serving ISO load, are based on the unspecified emission rate established by CARB of 0.428mTCO2/MWh". Assumes annual energy storage in TWH over 5 years; 1, 1, 2, 3, 3 http://www.caiso.com/Documents/GreenhouseGasEmissionsTracking-Methodology.pdf
Public Gas Grid – Electricity Storage Capacity as Renewable Natural Gas	100,000,000 MWH	100 TWH	**The California gas grid can store all curtailed renewable electricity as renewable natural gas. It can store about 33 times more energy annually than we anticipate will become surplus over the next five years.** **This leaves plenty of electricity storage capacity as we approach 60% renewables and a 100% climate-friendly 2045 energy portfolio goal.** **The California gas grid as battery is the largest existing energy storage device in the world!** https://ccst.us/wp-content/uploads/Summary-Report-v2.pdf Page 10 - 400 billion standard cubic feet (Bcf) of natural gas working capacity x 1 million dekatherms/Bcf x .29 MWH per dekatherm **https://www.eia.gov/naturalgas/storagecapacity/#tabs-map3**

Number of Power to Gas Plants Needed over 5 years			
Operating Hours / Day	20		Each power to gas plant will provide demand shedding electric grid relief during peak periods from 5-9pm.
Gas Grid Electricity Storage	20 MW		Each modular power to gas grid battery requires 20MW of power and about 5,000 square feet of land
Annual Gas Grid Electricity Storage	140,000 MWH		Each plant will operate 20 hours per day on renewable electricity, to charge the gas grid with carbon neutral renewable natural gas nearly all day, every day.
Use of Curtailed Renewable Electricity	20%		A 20% blend of low – negative priced power will significantly lower the average cost of running the hydrogen electrolyzer, the CO2 methanation (Electrochaea) and upgrading/compression (SoCalGas) processes for gas grid pipeline injection.
Annual Curtailed Power Stored	28,000 MWH		
Anticipated Annual Curtailed Renewable Electricity Oversupply in Five Years	3,000,000 MWH	3 TWH	
Power to Gas Plants (20MW) Required in California	**107**		**With around 100 Power to Gas Plants at a 20MW plant module size, oversupply can be stored for later use hours, weeks or months later, lowering average renewable energy costs, stimulating and de-risking renewable energy development, while realizing revenue from deploying clean stored energy during peak periods into CleanPeak gas fired peaking facilities with the attributes of GHG offsets** As oversupply increases, each plant may increase the use of curtailed power. If each plant were larger (lower cost/kW) or used 40% curtailed power, only 50 plants might be required. **California ISO**: "During oversupply times, wholesale prices can be very low and even go negative in which generators have to pay utilities to take the energy. But the market often remedies the oversupply situation and automatically works to restore the balance between supply and demand. In almost all cases, **oversupply is a manageable condition, but it is not a sustainable condition over time** — and this drives the need for proactive policies and actions to avoid the situation". http://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf

The California Gas Grid – Too Big to Fail			
California Gas Use (Yearly)	612,000,000 MWH	612 TWH	**The California gas grid throughput is twice the size of the electricity grid (612 TWH vs 300 TWH)** **https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_SCA_a.htm** 2,110 bcf/y x 1 million dekatherms/bcf x .29 MWH per dekatherm = 612 TWH.
Projected Gas Use Reduction by E3 by 2030 if Policies are Adopted Under the **California Energy Commission Natural Gas Distribution Infrastructure and Decarbonization Targets Initiative**	(44,000,000 MWH)	(44 TWH)	**This proposed policy shift from gas to electricity only represents a 7% reduction in gas flow (at an 80% current gas use efficiency). This would not justify an accelerated depreciation tax on gas buyers and $26B in taxes to subsidize gas to electric infrastructure and the quick retirement and decommissioning of the public gas grid. Additionally, the electric grid would need investment to increase throughput by 12%.** June 6, 2019 California Energy Commission Testimony: Question by Kevin Best (RealEnergy): How much new electricity do we need for this? Answer by Zach Subin (E3): 30-40 TWH
Note: Current Renewable Energy Curtailments in Germany and Britain	4,600,000 MWH	4.6 TWH	**Curtailed renewable energy in Germany and Britain cost over $400M to curtail and could have saved 2.1MT of CO2 if utilized**. https://www.sciencedirect.com/science/article/pii/S1364032118300091