



# Renewable Geothermal Power – Supercritical CO<sub>2</sub> Technology and California's Need for Flexibility

## TECHNICAL WORKSHOP ON CLEAN ENERGY ACROSS THE BORDER

FEBRUARY 18–19, 2016  
Holtville, California



John R. Muir  
4300 Horton Street, Unit 15  
Emeryville, CA 94608  
Office: (888) 320-2721  
[www.greenfireenergy.com](http://www.greenfireenergy.com)



## John R. Muir

- Senior Vice President – Business Development
- GreenFire Energy, Inc.
  - GreenFire Energy’s ECO2G™ technology could transform the global geothermal power industry by overcoming the risk and resource constraints that have severely limited hydrothermal projects, and will generate clean, safe and reliable power at competitive prices.
- MBA with 30 years’ experience focusing on disruptive technology development for large opportunity markets





## Andrew J. Van Horn

- Senior Advisor
- GreenFire Energy Advisory Board
- Ph.D. with 35+ years' experience as an economic, technical and regulatory consultant to utilities, EPRI, EPA, IPP generators, and energy and environmental market participants





# GreenFire Energy Inc. Reinventing Geothermal Power

## Mission

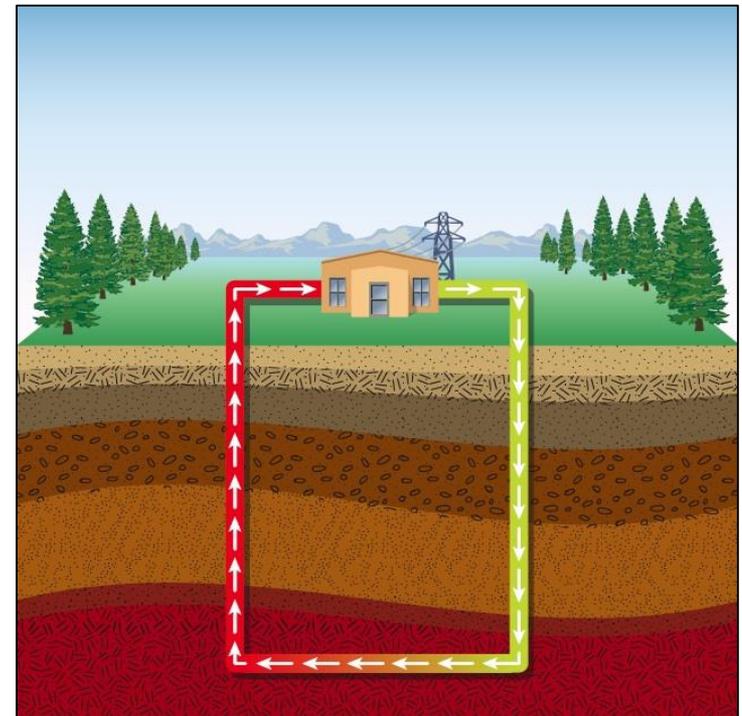
**Develop utility-scale CO<sub>2</sub>-based geothermal energy (ECO2G™) technology for global applications**

- Develop, demonstrate, and commercialize ECO2G™
- Identify, finance, develop, and operate sites in the United States and abroad

## Market

**Multi-billion dollar market for electrical power that increasingly requires:**

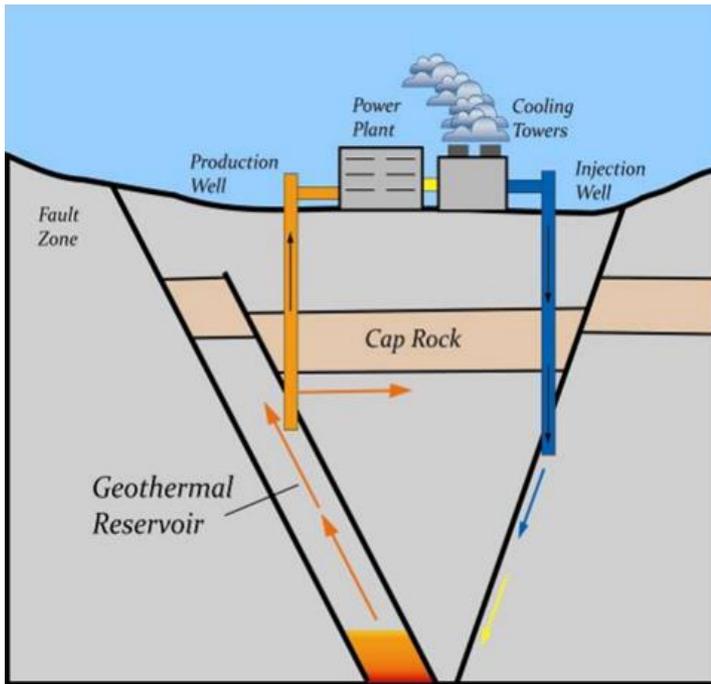
- Renewable fuel and power resources
- Zero carbon emissions
- Limited water consumption
- 24/7 baseload availability with flexible dispatch
- Commercial scale
- Competitive costs
- Global applications





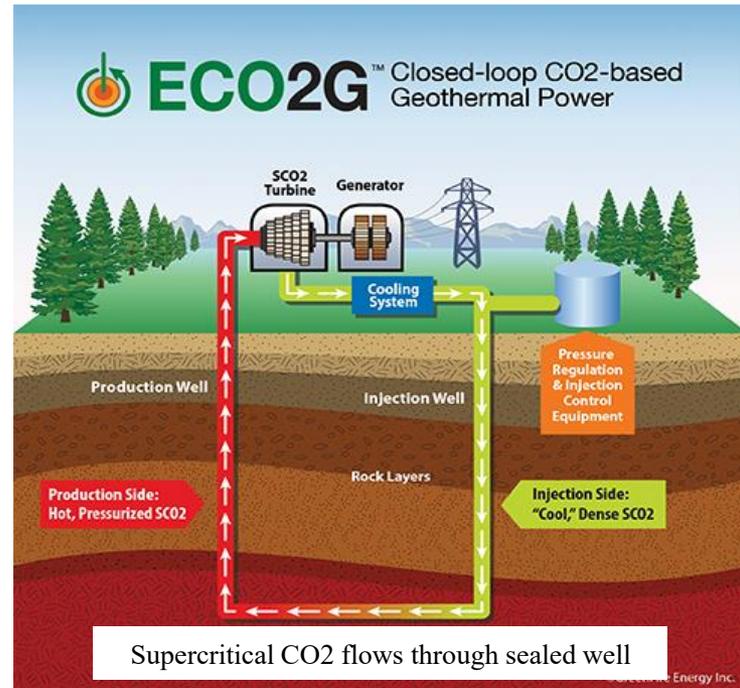
# ECO2G™ Revolutionizes Geothermal Power Generation

## Conventional Hydrothermal



**Requires heat, water and permeability**

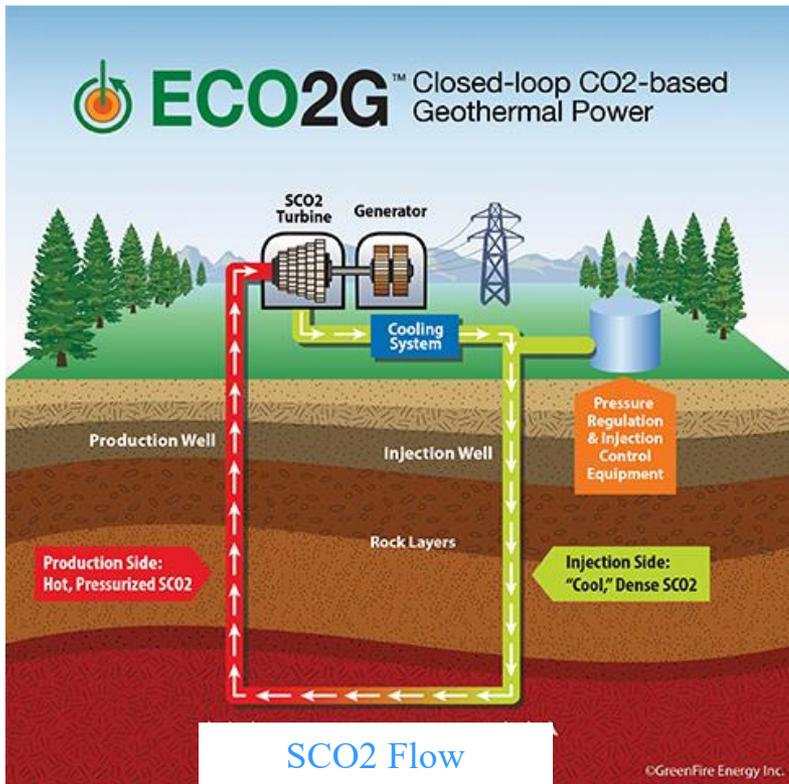
## Closed-Loop CO2 Geothermal



**Requires heat**



# ECO2G™: Advanced Technology Enables a Superior Business Model



## Expands the range of geothermal; globally replicable

- Generates power where EGS and hydrothermal cannot

## Lower risk and project time

- Virtually eliminates failed wells, the highest component of geothermal risk
- Can augment underperforming projects with no risk to existing system
- Easier permitting, reduced project timeframe
- Modular design scales up or down to match resource and demand
- Standardized components enable volume and learning curve cost reductions

## Higher efficiency and profitability

- Extracts much more heat from a given resource compared to hydrothermal
- CO2 turbines enable efficient power cycles
- Flexible power generation is very attractive to utilities

## Safe, environmentally sustainable

- No GHG emissions
- No geothermal process water consumption
- No fracking, shearing, or induced seismicity
- No waste streams
- No dangerous chemicals or explosives

***A Revolution in Power Generation***  
***Renewable, baseload utility-scale power that addresses both climate change and water consumption issues***



# Why California Needs Flexible Power

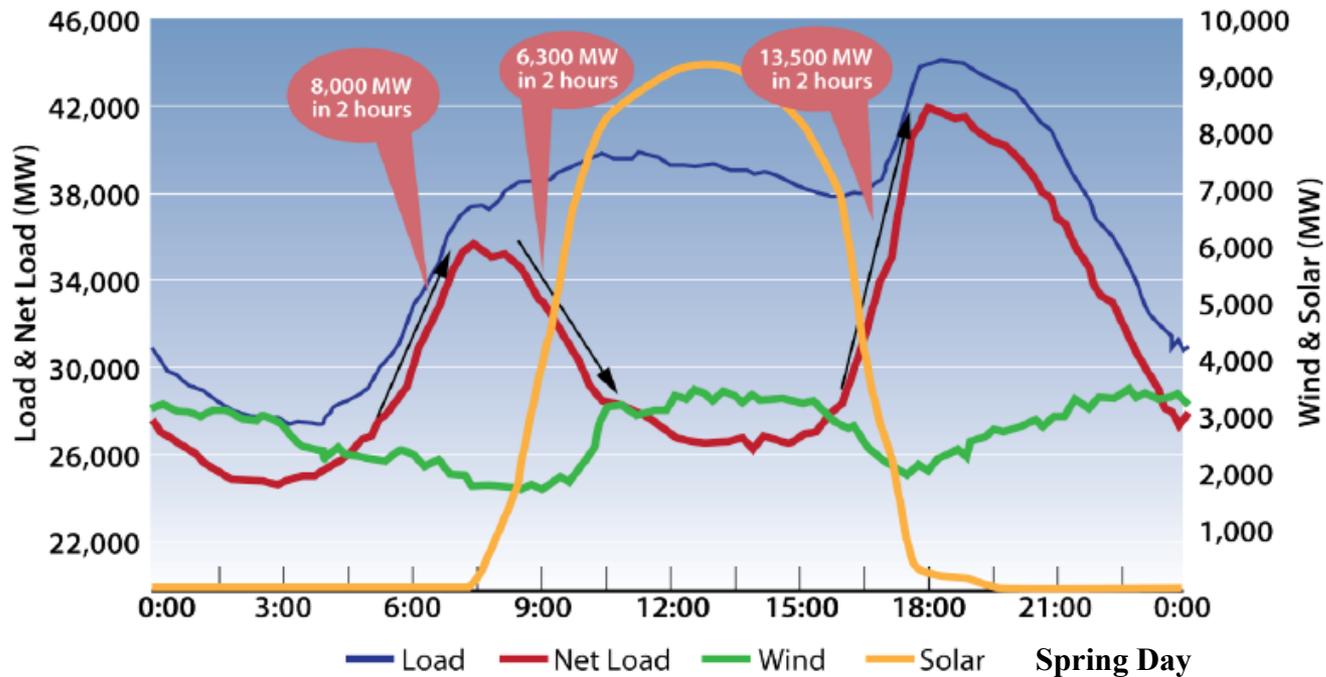


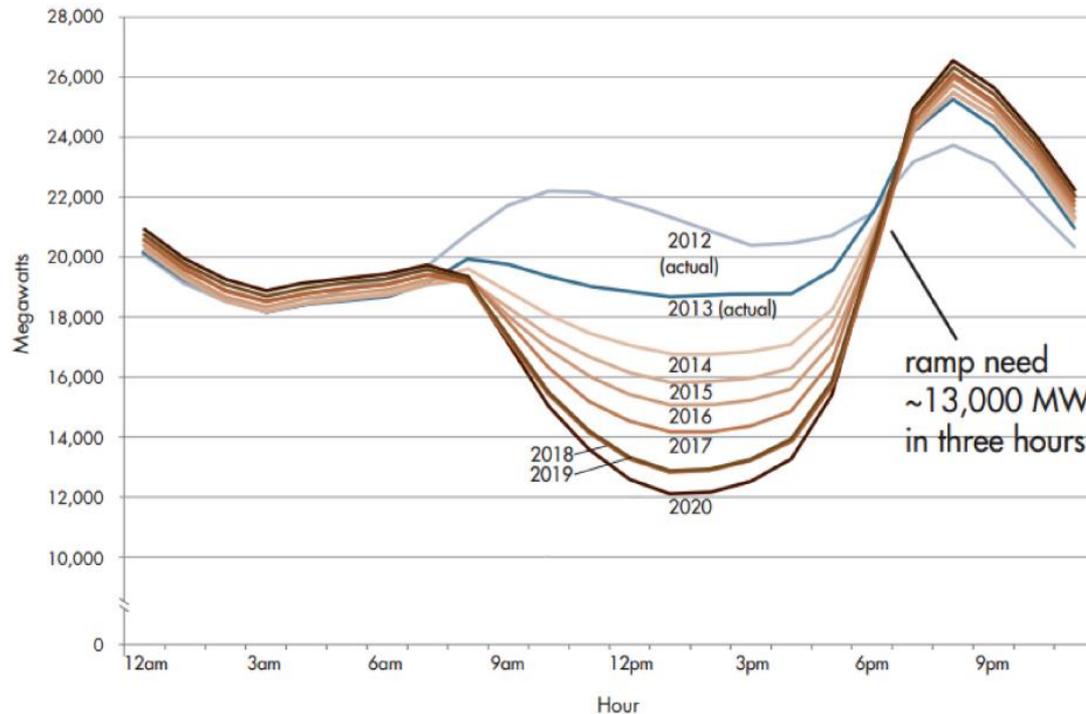
Figure 1.1. Forecasts of gross load, renewable generation, and net load in 2020

[Liu 2012]

Liu, S., 2012. Operational challenges to integrate 33% renewable generation, California Independent System Operator, Aug. 23, 2012.



# CAISO “Duck Curve” Net Loads & Projected Ramping Needs



March 31 Net Loads (2012-2020)

CAISO, CAISO Time-of-use Periods Analysis. Report filed with the California Public Utilities Commission in OIR.15-12-012, “Order Instituting Rulemaking to Assess Peak Electricity Usage Patterns and to Consider Appropriate Time Periods for Future Time-of-Use Rates and Energy Resource Contract Payments.” January 22, 2016, p.8.



# Flexibility Issues for Geothermal Power

- Technical: Cycling Steam Supply vs Bypassing Turbines
  - Challenges for wet & dry steam & brine
  - Potential advantages of ECO2G
- Economic: Lost Baseload Revenues
  - Redefining payments and products for capacity & ancillary services, while LMP energy prices decline
  - CAISO “flexi-ramp” & FERC products
- Regulatory and Contractual
  - Curtailment, reliability & other contract provisions
  - Revising CPUC “Least-cost, Best-fit” RFO criteria
  - Cost causation –Who should pay? How to pay?



## How to Increase Renewable Diversity

- Recognize geothermal power's renewable fuel attributes, 24/7 reliability and security of heat supply,
- Add new geothermal facilities designed to provide both baseload & flexible operations,
- Revise tariffs, contracts and payments,
- Carry out RD&D to level the playing field, e.g., by demonstrating ECO2G's innovative technology with no carbon emissions, no process water consumption and flexibility.



# Appendix: Additional Slides



## Barriers to Increasing Geothermal Power

- Technical barriers
  - Site feasibility and transmission availability
  - Declining conventional steam fields & unproductive wells
  - Reliance on current wet and dry steam generation technology
  - Need to integrate below- and above-ground design and demonstrate ECO2G
- Economic, legal, regulatory and contractual barriers
  - Wholesale power prices that pay for performance
  - Ancillary service/flexibility revenues that compensate for lost baseload revenue
  - Reduced interconnection costs/permitting, siting & licensing time
  - Restructuring of existing contracts and devising new contract terms
  - The usual financing & commercialization hurdles



## Research and Development Needs

- Identification of existing geothermal sites that would benefit from additional capacity,
- Simplification of permitting/licensing for greenfield sites and additions on existing sites,
- Testing and comparison of flexible operations at conventional & ECO2G geothermal.



## ECO2G Can Provide California:

- Renewable zero carbon power generation to help reach the RPS goal of 50% retail sales by 2030
- Reliable 24/7 dispatchable baseload generation
- Replacement baseload capacity as existing units retire
- Rejuvenation and expansion of existing geothermal power sites
- Development of additional geothermal resources that cannot be accessed with conventional technology
- Resource diversity to complement intermittent solar and wind
- Reduced water consumption
- Renewable fuel source with secure on-site delivery.



# GreenFire Energy Team and Relationships

## Management Team

- Joseph Scherer, CEO: Attorney/MBA with 30+ years experience in project finance including renewable energy
- Dr. Alan Eastman, Chief Technology Officer: PhD in chemistry with 37 patents, industrial experience
- John Muir, VP Business Development: MBA with several successful exits in technology ventures
- Mark P. Muir, Senior Consulting Scientist: MBA and geologist specializing in hydrogeology
- Joseph Osha, CFO : MBA/CFA with extensive public and private market experience in renewable energy

## Advisory Board

- Dr. Leland “Roy” Mink: Former Director of DOE Geothermal Technologies Program; expertise in geology, hydrogeology, and geothermal resource characterization
- Lou Capuano, Jr.: 40 years of geothermal drilling expertise; widely recognized industry expert; current President of the Geothermal Resources Council (GRC)
- Halley Dickey: 40 years of experience in power generation systems development; expert in geothermal power system design and SCO2 turbines
- Dr. Andy Van Horn: 35+ years experience as economic, technical and regulatory consultant to utilities, EPRI, EPA, IPP generators, and energy and environmental market participants

## Collaborating Research Partners

- U.S. Department of Energy
- Lawrence Berkeley National Laboratory
- Pacific Northwest National Laboratory
- University of Utah
- Electric Power Research Institute



## GreenFire Challenges/Requests

- Funding to study the potential for re-invigorating existing sites such as The Geysers, Coso and Imperial Valley
- Fast-track permitting of ECO2G installations within conventional geothermal project sites
- Recognition of the importance of clean geothermal power to:
  - balance California energy requirements,
  - meet renewable power goals,
  - reduce water consumption and carbon emissions.



## *ECO2G Unique Capabilities*

- Greatly expands the range of geothermal power
  - Does not depend on natural fractures (permeability)
  - Reduces consumption of increasingly scarce water
  - Uses much higher percentage of a given resource
  - Accesses heat that conventional geothermal can't use
- Substantially reduces risk and project time
  - Sufficient heat is the main requirement; reduces drilling risk
  - Scalable in 1 to 5 MW increments to match supply needs over time
  - Easier permitting (no fracking, injection, waste water)