

# All Steam Coal Gasification

more efficient, lower-cost and cleaner production of

## Blue Hydrogen

April 2022

*Making decarbonization and efficient affordable  
hydrogen production a reality*



# Overview & WES's Objective

## **WES's Vision**

Provide the world with economical gasification systems for producing Hydrogen & power using CCS - Aid climate change by making Carbon Capture possible without cost penalty

## **WES's Objective**

To find the most capable Strategic Partners and Investors to complete development of the WES technology & create a path to commercial deployment

## **Differentiators**

**WES's ASG technology greatly reduces the cost of gasifying coal & other feedstocks (by more than 40%)**

- **Economically produce Hydrogen and/or power and/or syngas for chemicals, plastics, etc. with**
- **Ready for development Partner/Investor to aid component testing & Process Development Unit (PDU) construction and operation to produce Process Design Package (PDP) for a pilot plant**

# Goal & Focus of WES Gasification Technology

## Goal

**Significantly reduce the cost of Gasification with Carbon Capture & Sequestration to create competitive Hydrogen & Power Plants, while mitigating Carbon Emissions and providing robust, operable, flexible designs globally**

## Focus

- **Cost reductions to provide competitive Hydrogen**
  - WES's unique Gasification Plant technology combines All Steam Gasification (ASG) with Micronized Char and an Indirect Gasifier to achieve:
    - Gasification Plant cost reductions of 40% using equipment, significant structural and size reductions, increased gasifier capacity, and by eliminating a large ASU.
    - Cost reductions of 20% on large scale, sCO<sub>2</sub> single train Oxy gasification plants. (Does not include reduced interest during construction from faster construction time.)
- **Efficiency - All Steam Gasification (ASG)**
  - More hydrogen from the same amount of coal, combined with no large ASU, increases IGCC with Carbon Capture plant efficiency from conventional levels of 32 % to as high as 42 % HHV – the ASG requires less Coal per MWe
- **Robust, operable, flexible gasification system** to integrate with variable renewable energy requirements

# What it is

A revolutionary technology for gasifying coal, biomass or plastics **WITHOUT BURNING** it.

Reducing it to useful molecules  
**(especially Hydrogen)** for commercial use.

While capturing the carbon instead  
of emitting to the atmosphere.



# Why it's Needed

Coal-burning is the single largest cause of increasing CO<sub>2</sub> in the atmosphere today.

Despite renewable energy in US and Europe, worldwide coal-burning is actually increasing – especially in fast growing nations in Asia.

Meanwhile, **Hydrogen** is beginning to replace fossil fuels globally, and the world needs inexpensive ways to produce it – which WES offers.



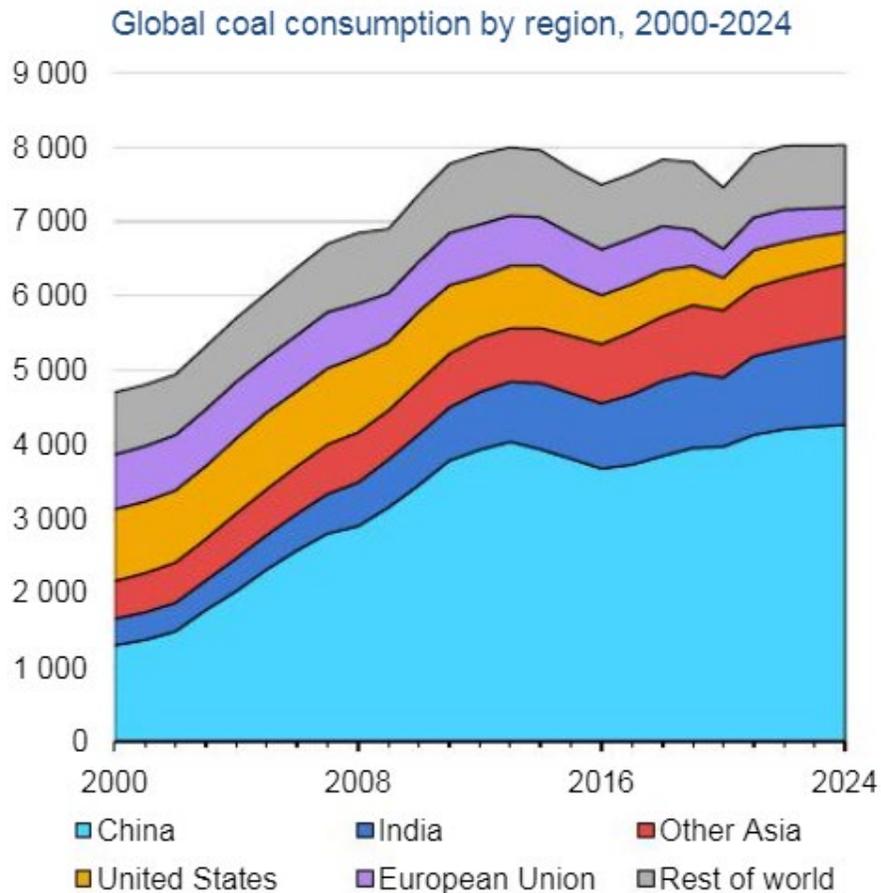
The world will not stop using coal so we must **CHANGE HOW** the world uses it.



By gasifying, not burning coal, the CO<sub>2</sub> and pollutants can be economically captured instead of emitted.



# Coal & Climate: The Stark Reality



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- Decline of coal in US & Europe masks rapid rise in coal use in China, India, rest of Asia
- Amid many climate challenges, this is perhaps the key one – by itself, it puts all climate targets out of reach
- Parts of the US and other nations will keep using coal – WES can help change how they do it
- Carbon capture & sequestration (CCS) is needed but the perception is that it is still too costly.

***WES ASG reduces cost and increases efficiency enough to make CCS affordable***



**Potentially Enormous  
Market for Producing Blue Hydrogen  
From Low-Cost  
Coal Gasification with CO<sub>2</sub> Capture**

# Global Hydrogen Market Growth

Hydrogen market size exceeded \$150 billion in 2020 and is anticipated to grow to over \$300 billion by 2027 - CAGR of over 9.2%



- Development of decarbonization and climate mitigation policies will propel hydrogen market share
- Focused long-term investments toward development of early-stage technologies will propel hydrogen market

# The Hydrogen Transformation is Local & Global

**Always remember: For the foreseeable future, nations around the world will still get the majority of their hydrogen from coal. Without CCS, it's a climate disaster.**

- US DOE released “Development Report on Hydrogen Energy and Fuel Cell” in 2015. Ten US States issued policies on Hydrogen and Fuel Cell Vehicles in 2016. 55 Hydrogen stations in US were built as of 2019.
- The European Union has issued “Implementation Plan on Hydrogen Energy and Fuel Cells” in which Hydrogen and Fuel Cells will be equipped on vehicles in 2020
- The Hydrogen Council – a global initiative of leading energy and transport companies – has been formed to accelerate the investment to transition to Hydrogen.
- In China, the NDRC “Action Plan on Energy Revolution” defined its “Route Map on Hydrogen Energy and Fuel Cell.” 100 Hydrogen stations were built as of 2019, and 1,000 to be built by 2030.
- Japan issued a “Route ap on Hydrogen Energy and Fuel Cells“ in 2014, under which 5.3 million cells are to be manufactured by 2030.

**WES gasification represents a technology breakthrough:** Much less costly, much more efficient and cleaner than other systems, even with CO<sub>2</sub> capture.

The WES ASG works with more than just coal, it can also **produce hydrogen from blended biomass or plastics feedstock.**

WES will be commercially attractive tapping potential multi-trillion-dollar market – and helping save climate.

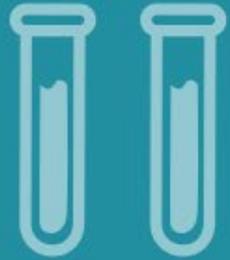


# The Solution

- WES invented breakthrough ASG for Blue H<sub>2</sub> to help fulfill the energy demand to build a H<sub>2</sub> Economy
- ASG is much lower cost and much more efficient, which is a strong incentive to produce affordable H<sub>2</sub> from coal (including biomass or recycled plastics). The WES ASG with CCS can produce Blue H<sub>2</sub> at low cost – and can also produce syngas for methanol, plastics, chemicals, fertilizers, and power.
- The WES ASG system is not limited to coal as a feedstock – its commercial use will simply be demonstrated in this Blue Hydrogen project.
  - The WES ASG system can also be used anywhere in CCS projects that use other feedstocks to produce Hydrogen – including biomass (wood waste, agricultural waste, etc.) and/or plastics
- WES has an outstanding R&D and Engineering Team that includes globally-recognized gasification experts and world-renowned EERC and PSRI Gasification Labs in the US
- **Validation of the WES solution:** H<sub>2</sub> production with CO<sub>2</sub> capture is “Blue Hydrogen” which is highly valued globally. An Asian client, with extensive previous gasification experience, found that **only the WES ASG** is suited to be their Blue Hydrogen plant’s gasifier system – other gasifiers have higher costs, lower efficiency, and are unable to gasify lignite.

# How it Works & Why it's Better

In a gasifier for coal (or biomass blend and plastics) nothing is burned! Coal is a chemical feedstock, not a fuel.



Coal is made into char, reduced to fine powder and then gasified with steam to create synthesis gas (“syngas”) rich in commercially useful Hydrogen.



CO<sub>2</sub> captured from the syngas is available for geological sequestration and useful products.



Other impurities and pollutants (e.g. mercury, sulfur particulates) are also removed without fuel combustion.



# Breakthrough WES Gasification Technology

**WES gasification is 40% less costly & H<sub>2</sub> is 20% less costly than DOE numbers**

**All Steam Gasification uses Steam to provide Oxygen + H<sub>2</sub> instead of an ASU:**

- Saves large ASU – 12% Plant Capital compared to Depart of Energy (DOE) Base Line – Also no Black Water system
- Saves ASU Aux. Power – provides 20 % more net output against DOE IGCC Base Line (10% H<sub>2</sub> only plant)
- 3x faster gasification than normal allows smaller Equipment and Modularization. Gasification < 1 second

**Modular, Indirect, Fluid Bed Gasifier allows use of Hydrogen and air instead of Oxygen for Gasification Heat:**

- Providing syngas fuel without N<sub>2</sub> for Hydrogen applications.
- Variety of coal incl LRC and lignite and use of Biomass/Plastics can provide Net Negative Carbon
- Allows POC complete heat and energy recovery from very clean stream- Essentially no CO<sub>2</sub>
- Alternatively, the WES gasifier combustor can operate with O<sub>2</sub>/CO<sub>2</sub> and syngas to match oxycombustion supercritical CO<sub>2</sub> cycles – for example, with Allam Cycle

**Devolatilizer/Micronizer combines pyrolysis (DOE) for Char with Pulverizer (WES/EERC/PSRI) to 20 Micron size:**

- Another 3x faster than normal –gasification in 1 sec – again reduces size for modularization - 3 ft diam. for 640 MWe
- Previous testing by EERC shows potential for micronizing in the devolatilizer

**POC System (WES) provides low cost N<sub>2</sub> and Steam to GTs for diluting H<sub>2</sub> suitable for Advanced H<sub>2</sub> GTs (DOE)**





WES gasifier uses steam (which is  $H_2O$ ), not oxygen or air. By chemically reacting with the coal's carbon, it boosts production of hydrogen, the desired product.



Eliminates expensive, large footprint equipment other gasifiers require, e.g. no large oxygen plant needed



Higher efficiency and smaller equipment allow modular and faster construction, smaller footprint, fewer materials – which means much lower costs

# WES ASG Projected Cap. & Op Economics vs H<sub>2</sub> Costs

WES leads the way.

*“First Energy Earthshot aims to slash the cost of clean hydrogen by 80% to \$1 per kilogram in one decade”*

Secretary of Energy Jennifer Granholm, June 2021

WES ASG H<sub>2</sub> initial cost is projected to be 0.88 to 0.80 x \$1.63 (DOE figure) = \$1.30 to 1.43 \$/kg

DOE Hydrogen Production Costs vs WES ASG Impact on Hydrogen Production Costs					
Technology	Coal Gas w/CCS	ATR w/CCS Methane	Wind Electrolysis	Solar Electrolysis	ASG Coal Gas w/CCS
H <sub>2</sub> Cost	1.63 \$/kg	1.48 \$/kg	5.96 \$/kg	8.19 \$/kg	1.43 \$/kg

# WES Company Overview

WES is a US technology development company focused on the development and commercialization of advanced, low-cost, high-efficiency, near-zero-emissions coal and biomass gasification technologies, for application to the H<sub>2</sub>, chemical and power industries, and to help mitigate climate change.

- Built an outstanding R&D, engineering and business team of world-class gasification experts and industry leaders, including Energy & Environmental Research Center (EERC) and Particulate Solid Research, Inc. (PSRI)
- Developed major breakthroughs in coal lignite, biomass and plastics gasification systems for Blue H<sub>2</sub> production with CO<sub>2</sub> capture, near-zero emissions, and with lower cost than other gasification systems
- Won two contracts & completed two Gasification System Concept Designs in 2019 for US DOE

# The WES Team:

## Leading Experts with Devoted Careers in ASG Technology for CCS & Climate

The WES team brings over 200 years of combined industry expertise to the company. For the last 6 years, they have devoted themselves to developing the ASG technology and CCS for WES. See slides 24 & 25 in the appendix for more detail and a complete list.

- Dr. Tom Fletcher: Professor, Brigham Young University, USA - Gasification and Pyrolysis (30 yrs)
- Chris Higman: Managing Director, Higman Consulting (formerly Lurgi), wrote the book “Gasification”. Gasification and Syngas Technology expert (30yrs)
- Dr. Reddy Karri: Consulting Director, PSRI; Particulate Technology and Fluidization (28 yrs)
- Francis Lau: Consultant EverBright & Associates LLC, Former CTO SES Gasification (35 yrs)
- LIANG Shipu (Steve): Former Head, Coal Conversion at Shenhua, Houston-based engineering consultant (20 yrs)
- Joshua (Josh) J. Stanislawski: Director of Energy Systems Development at the EERC (20 yrs)
- Eric (Ric) Redman : Former CEO Summit Power Group; CEO Thunderbolt Clean Energy LLC (40 yrs)
- Doug Todd: Former President, Process Power Plants; Former GE, IGCC Power Plants (55 yrs)

# Validity of Claims

- **Brigham Young University testing shows that the combination of Steam Gasification and Micronizing is 6-16x faster than normal gasification (< 1 sec. vs 6 sec. residence time in DOE Concept Design)**
- **EERC testing of char shows micronizing can be accomplished in WES Devolatilizer**
- **DOE CoalFIRST award produced WES Gasifier Concept Designs by EERC, PSRI and WES**
- **Worley Group Techno-Economic studies for the LCOE of the Concept Design Gasifier Plant showed cost reductions are available by integrating WES gasifier with WGPU, Spray SG Coolers, and various capture technologies.**
- **Worley costing of the Concept Design Gasification components for WES China H<sub>2</sub> plant project showed and compared USA & China costs against DOE Baseline studies leading to the conclusion of lower cost H<sub>2</sub>**

**Next Step – Proof Testing**

# Conclusion

**WES is ready for the next three phases of the ASG Development Plan (See details next page)**

- **Phase 1: Bench scale testing of Concept Design features – EERC cost quote of \$6M**
- **Phase 2: That leads to PDU – Phase 2 – EERC cost quote of \$13M**
- **Phase 3: PDP from PDU leads to Pilot Plant, whose PDP leads to Commercial Plant**

**WES Seeks Technology Partners and Investors for the Next 3 Phases.**

***The WES ASG is not just another gasifier – it can help make decarbonization and efficient hydrogen production affordable***

# WES ASG - Technology Development Investment Plan

Activity	Complete	Investment
<p>Core Feasibility Study by WES Experts - DOE Request – <b>Modeling &amp; Lab Scale Testing by BYU &amp; EERC</b></p> <ul style="list-style-type: none"> <li>• PFDs, H&amp;MBs, Preliminary Plot Plan, Elevations &amp; Costing for IGCC &amp; PolyGen Plants</li> </ul> <p>DOE CoalFIRST Initiative – WES ASG PolyGen and Coal Allam Cycle Power Systems</p> <ul style="list-style-type: none"> <li>• Conceptual Designs, Cost &amp; Performance, Economics &amp; Development Pathway</li> </ul> <p>China Client/WES Collaboration - ASG Hydrogen Plant Design and Development</p> <ul style="list-style-type: none"> <li>• <b>Commercial Hydrogen Plant Modeling &amp; Costing for ASG Assessment</b></li> </ul>	Complete	\$6,000,000
<p>Phase - 1 - Bench Scale Testing &amp; Full-Scale Due Diligence Study – USA EERC, PSRI</p> <ul style="list-style-type: none"> <li>• <b>Technology Development Bench Scale testing</b> <ul style="list-style-type: none"> <li>• <b>Devolatilizer/ Indirect Gasifier</b></li> </ul> </li> <li>• Design Optimization Study for Hydrogen &amp; PolyGen Plants           <ul style="list-style-type: none"> <li>• Aspen Modeling, Due Diligence Study (Including layout, elevations &amp; costing)</li> </ul> </li> <li>• Detailed Development Plans for PDU - Process &amp; Design</li> </ul>	2022	Seeking \$6,000,000
<p>Phase - 2 - Gasification Proof of Concept - Process Development Unit (PDU) – USA EERC, PSRI</p> <ul style="list-style-type: none"> <li>• 7 - 10 TPD PDU - Char Prep, Devolatilizer, Gasification, S. G. Cooling, Filter</li> <li>• Cold Flow Test - Followed by Hot PDU</li> <li>• Detailed Development Plans for Phase 3 Pilot Plant</li> </ul>	2023	Seeking \$13,000,000
<p>Phase - 3 – <b>Gasification Pilot Plant</b> - USA~ 25 MWe equivalent <b>at 1/30 scale</b></p>	2025	From Phase 2

# Thank You

*Making decarbonization and efficient affordable  
hydrogen production a reality*

For more information contact:

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Henk Abbink [henk@greenchi.com](mailto:henk@greenchi.com)



# Appendix

## **Bios for WES Technical & Business Advisory Boards**

# Bios for WES Technical Advisory Board

## Top Gasification Experts in the Industry

### **Dr. Tom Fletcher: Professor, Brigham Young University, USA - Gasification and Pyrolysis**

Dr. Fletcher is a professor at Brigham Young University (BYU) and a former senior member of the technical staff at Sandia National Laboratories. With more than 30 years of experience in coal research, he is a world expert in pyrolysis of coal and low-grade fuels. Dr. Fletcher has been on the faculty at BYU since 1991 and is currently serving as its Chair. He is also the Director of the Advanced Combustion Engineering Research Center (ACERC), which performs about \$2 million in research per year. He received a PhD in Chemical Engineering from BYU.

### **Chris Higman: Managing Director, Higman Consulting GmbH. – Gasification Technology**

Mr. Higman is internationally renowned in the gasification industry with an established client base in six continents. In over 25 years at Lurgi AG, he was Project Manager for a number of integrated plants for the production of chemicals, fuels, and power, mostly based on gasification processes, he assumed responsibility for all process design and development efforts in the company's gas production, treatment and synthesis sector. He graduated from Oxford University, U.K. and the University of the Witwatersrand, Johannesburg, South Africa with degrees in Mathematics (B.A.) and Mechanical Engineering (M.Sc.).

### **Steve Jenkins: Principal, Energy and Chemicals Consulting - Gasification Plants**

Steve Jenkins has over 40 years experience in the process and power industries, with a specialization in permitting, design, and operation of gasification facilities using coal, pet coke, biomass, biosolids, municipal solid waste and blends, for generating electricity and for producing chemicals, liquid fuels and ammonia-based fertilizers. Mr. Jenkins is currently a principal at Energy & Chemicals Consulting LLC. Prior to this he was VP, Gasification Services at CH2M Hill, Inc. He has conducted feasibility studies for assessing technical and economic capabilities of small and large-scale gasification projects. Jenkins brings WES experience in moving gasification technologies from pilot to commercial scale. He received his BS in Chemical Engineering from the University of South Florida.

### **Dr. Reddy Karri: Consulting Director, PSRI; Particulate Technology and Fluidization**

Dr Karri brings 28 years experience in particle technology and fluidization to the WES team. His experience includes FCC technology, cokers, polyolefin, methanol to olefins, maliec anhydride, acrylonitrile, TiO<sub>2</sub>, polycrystalline silica, gasification, pyrolysis, sulfur capture, CO<sub>2</sub> capture, biomass and radioactive materials. His current responsibility at PSRI is to build and manage the firm's consulting resources for the PSRI membership providing state of the art equipment design, effective process design concepts, first to market development methodology and start of the art training. Dr. Karri holds a PhD and MS in Chemical Engineering from University of New Hampshire and a BS in Chemical Engineering from IIT, India.

### **Eric (Ric) Redman: CEO Thunderbolt Clean Energy LLC – Senior Electric Power Executive**

Ric is the former President & CEO of Summit Power Group, an independent developer of climate-friendly power projects, including proposed coal gasification projects with carbon capture. Ric is member of the Board of Directors of the Global Carbon Capture & Storage Institute (GCCSI), as well the Advisory Board of Scottish Carbon Capture & Storage (SCCS). He is a Senior Policy Fellow for Energy & Climate at the University of California San Diego's graduate School of Global Policy and Strategy, where he is a member of the Deep Decarbonization Initiative (D2I).

# Bios for WES Technical Advisory Board

## Top Gasification Experts in the Industry

### **LIANG Shipu (Steve): Technical Advisor & Engineering Consultant – Gasification Systems**

In China, Mr. LIANG was head of all gasification and coal-to-chemicals projects for Shenhua, the world's largest coal company and world's largest gasification company. He installed and commissioned all key commercial gasifiers for Shell, General Electric, Siemens, East China University of Science & Technology (ECUST). Steve commissioned 24 full-scale Ningmei gasifiers of indirect coal liquefaction (F-T) at the plant in Ningxia, China in 2016. For this work, the Ningmei team received a commendation letter from President Xi Jinping.

Steve, brings 20 years in coal gasification, holds many patents on coal converting and won the Gold Medal on outstanding patented invention from the World Intellectual Property Organization. Steve also won the first level award of National Science and Technology Progress issued by State Council of the People's Republic of China. He moved to the US in 2017 under the US "Genius Visa" program. Steve is a graduate of Daqing Petroleum Institute and is a professor of China Petroleum University.

### **Joshua (Josh) J. Stanislawski: Director of Energy Systems Development at the EERC,**

Mr. Stanislawski leads a multidisciplinary team of scientists and engineers focused on research, development, and commercialization of innovative energy technologies as they relate to coal utilization and emissions, carbon management, and alternative fuels and renewable energy. Prior to his current position, he served as a Principal Process Engineer in the Energy Systems Development group at the EERC. He holds M.S. and B.S. degrees in Chemical Engineering from the University of North Dakota.

Mr. Stanislawski's principal areas of interest and expertise include coal and biomass gasification systems with an emphasis on novel syngas cooling, cleanup, and separation technologies. He has worked extensively with hydrogen separation membrane systems and liquid fuels catalysis. He is proficient in process modeling and systems engineering including techno-economic studies using Aspen Plus software. He has significant experience with process engineering, process controls, and project management.

### **Doug Todd: President, Process Power Plants - Former GE, IGCC Power Plants**

Mr. Todd is an internationally renowned expert in IGCC and Combined-Cycle Power plants. Currently Todd is President of Process Power Plants LLC, a consulting firm with more than 20 major industry and government clients. With over 50 years of experience, including 35 years with GE in Engineering, Marketing and Product Management positions culminating with Management responsibility for GE's Process Power Plants Organization. His experience includes 15 IGCC projects with 7 different gasification technologies. He is a member of AIChE, the Global Syngas Technologies Council (GSTC) and has published numerous technical papers for ASME, IChemE, EPRI, MIT and GTC. He received the first European IChemE Medal for Excellence in Gasification in 2002 and the GTC Lifetime Achievement Award for IGCC in 2003.

# Bios for Business Advisory Board From Key Fields of Expertise

## **Geoff Kerr: Technology Marketing & Communications Professional, Former SAP Executive**

Mr. Kerr has over 25 years experience in high-tech marketing, branding, and communications. His marketing tenure includes working in venture-backed start-ups as well as Global 1000 companies. Before his career as an executive at SAP he led marketing, communications, branding, and investor relations for several start-ups, one of which, USWeb, made its IPO in 1997. Kerr also worked in two premier agencies in Silicon Valley, Regis McKenna Inc, and Cunningham Communications. Kerr has a BA in History from Denison University.

## **Alicia Kruger: Policy Analyst, & Communications specialist on Energy, Climate, & Cleantech**

Ms. Krueger provides strategic qualitative and quantitative support to clients involved in policy and project development. Previously, she worked with the United Nations Framework Convention on Climate Change (UNFCCC) communications office in Bonn, Germany and with Bingham, Osborn, and Scarborough, a boutique wealth management firm in San Francisco, California where she helped to develop the firm's socially responsible investment offering. Ms. Krueger earned her Master of Public Policy at UC San Diego's School of Global Policy and Strategy (GPS).

## **Eric (Ric) Redman: CEO Thunderbolt Clean Energy LLC – Senior Electric Power Executive**

Ric is the former President & CEO of Summit Power Group, an independent developer of climate-friendly power projects, including proposed coal gasification projects with carbon capture. Ric is member of the Board of Directors of the Global Carbon Capture & Storage Institute (GCCSI), as well the Advisory Board of Scottish Carbon Capture & Storage (SCCS). He is a Senior Policy Fellow for Energy & Climate at the University of California San Diego's graduate School of Global Policy and Strategy, where he is a member of the Deep Decarbonization Initiative (D2I).

## **Kenneth Stenton: Founder & Former CEO Arradiance, Inc. – Business Executive & Entrepreneur**

Mr. Stenton is a seasoned executive and entrepreneur with over 35 years of experience in all aspects of business management in technology-related industries around the world. He has held division President, VP, GM and CEO positions at several global Automation and Instrumentation companies. Ken has built a patent portfolio of over 12 issued and 20 pending patents including four patents for novel microchannel amplifiers and photomultiplier devices. He is also Adjunct Professor of Business for State University of New York (SUNY) Stony Brook, NY. Ken obtained his BS in Physics from the UCLA and an MBA from The Wharton School of the University of Pennsylvania

## **Doug Todd: President, Process Power Plants - Former GE, IGCC Power Plants**

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## **Donald Weeden: Chairman of the Board of WES – Financial Executive and Investor**

Mr. Weeden is the former Chairman of Weeden & Co., a Wall Street Investment Bank. Mr. Weeden served as a trustee of the Weeden Foundation from its establishment in 1963 until retiring in 2019. The Foundation supports innovative environmental initiatives addressing issues such as the protection of ecosystems and wildlife, as well as population stabilization and sustainable consumption. He is a graduate of Stanford University.