# Osmotic Heat Engine for Energy Production from Low Temperature Geothermal Resources

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Chief Technology Officer
Oasys Water Inc.

# Mandatory Overview Slide

- Timeline
  - Project start date: June 1, 2010
  - Project end date: December 31, 2012
  - Percent complete: 0% as of May 1

- Budget
  - Total project funding: $1,821,997.00
  - DOE share: $910,997.00
  - Oasys share: $911,000.00
  - Funding received in FY09: $0
  - Funding for FY10: ~$450,000

- Barriers: Efficient use of low temperature geothermal resources

- Partners: AltaRock Energy Inc.

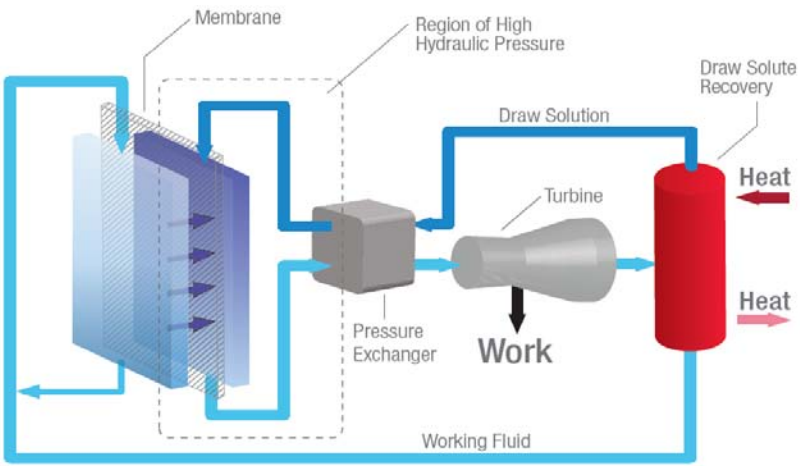
# Relevance/Impact of Research

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- The primary objective of this project is to demonstrate the economic viability of an Osmotic Heat Engine for electricity production from extremely low-grade geothermal resources
- The award can be broken into three key components:
  1. Optimization of stripper/absorber system in the OHE to accommodate site specific geothermal resources
  2. Integration of the OHE system into an EGS recovery plant
  3. Operation of the OHE system under different testing conditions to optimize performance and cost effectiveness of low-grade geothermal recovery
- Geothermal power is an attractive potential source for sustainable energy production, but the high heat temperature requirements (typically >250° C) of most geothermal capture systems reduce the geographic distribution and economical viability of geothermal energy production
- A thermal energy conversion process capable of economically converting lower temperature heat sources (40-100° C) into power would enable the use of much shallower wells, would reduce the risk associated with deep well injection systems, and would expand the geographical range of geothermal energy production
- Low-temperature heat capture systems are also critical for improving the economic viability of existing geothermal harvesting systems, such as Enhanced Geothermal Systems (EGS). EGS expands the geographic range of geothermal energy production by injecting water into bedrock to harvest high quality heat, but the engines used to convert geothermal energy to electricity (Stirling, Rankin, or Binary) cannot utilize heat below 70° C
- <u>Economically viable systems for harvesting low-grade heat (40-100° C) from geothermal sources will enable significantly enhanced sustainable energy production</u>

# Scientific/Technical Approach

- Oasys has developed a transformative Engineered Osmosis (EO) technology that enables cost effective energy production from extremely low temperature geothermal sources
- The osmotic heat engine (OHE) is a closed cycle pressure retarded osmosis (PRO) system capitalizing on low temperature heat to recycle an engineered osmotic draw solute.
- The **sole input** to this closed loop heat engine is low-grade heat (40-100° C); the **only output** is electricity from hydropower turbine
- The OHE uses lower temperature heat than any economical engine cycle on the market today, and the compact, closed loop system design enables integration of the system with existing high-grade conversion systems to improve energy recovery and reduce cooling costs



# Scientific/Technical Approach (cont.)



- Three phase approach:
  1. Feasibility and Engineering Design
  2. Procurement, Fabrication and Installation
  3. Field Operation

- Testing data from process components will go through rigorous review from the Oasys SAB members (biographies on slide 12)

- Use of existing vendor relationships for Oasys Water treatment technology

- Project Milestones:
  – Well Selection and Characterization
  – Stripper and Absorber Optimization
  – Membrane Development
  – Module Development
  – Membrane Module Testing
  – Integration of OHE system
  – Integrated System Demonstration (Go/No-Go Decision Point)
  – Fabrication of Pilot Plant
  – Pilot Operation
  – Final Techno-economic Analysis and Cost Projections

# Accomplishments, Expected Outcomes and Progress



- Wrapping up our technical staffing process
- Formalized key vendor relationships for core process components:
  - Membrane manufacturing
  - Solute recovery systems
- Set to officially begin work June 1
- The Oasys team includes the original inventors of the OHE from Yale as well as industry expertise in water and resource recovery (biographies on slide 11)

# Project Management/Coordination



Keys to project success will be:

- Existing relationships with local vendors
- Combined project experience among PI, engineering team and SAB
- Efficient use of project resources – as a startup, Oasys understands how to stay on, or under, budget

<u>2010</u>

Q2:

- Begin membrane chemistry testing and module development

Q3:

- Specify, purchase solute recycle system
- Identify and purchase pilot scale turbine and Pressure Exchanger (PX)
- Design integration of modules, PX and turbine

Q4:

- Construct membrane skid and connect to contracted solute recycle skid
- Begin in-house testing of OHE pilot

<u>2011</u>

Q2:

- Begin testing OHE pilot at geothermal site

# Future Directions



- Successful pilot demonstration of the Oasys OHE system will enable the company to devote more resources to scale-up of the technology for commercial use
- Upcoming milestones include PRO membrane testing and solute recycle system design
- Keeping a close eye on membrane chemistries from leading universities working on PRO membranes to incorporate best available technolgy
- Goal is to complete component design, fabrication and integration of a system for in-house testing by Q4 2010
- Field testing in 2011/2012 will enable more accurate cost projections and optimized designs for commercial scale OHE facilities

# Mandatory Summary Slide



- Efficient, unsubsidized electricity production from geothermal resources
- Allows for 24/7 production of energy if needed, or the ability to store and deliver only when needed most
- Successful demonstration of the OHE will open new range of geothermal that's not currently usable
- Allows for increases in efficiency in all thermal generation processes

# Supplemental Slides

# Oasys Management Team

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- **Aaron Mandell, Chief Executive Officer**: Co-founder & CEO of Oasys. Founder of several successful energy companies including GreatPoint Energy, Coskata and Altarock. Previously CTO and co-founder of GreatPoint Energy.

- **Dr. Rob McGinnis, Chief Technical Officer**: Dr. McGinnis is co-founder and CTO of Oasys. He is the inventor of the Oasys process and a recognized leader in the development of forward osmosis systems.

- **Edward Freedman, SVP & General Counsel:** Mr. Freedman was previously General Counsel and VP Operations at Ensemble Discovery. Prior to joining Ensemble, Ed was Vice President and General Counsel of Flagship Ventures.

- **Dr. Rick Stover, VP Engineering**: Dr. Stover is responsible for Oasys' engineering, product development and commercialization efforts. Previously Rick was CTO of Energy Recovery Inc (NASDAQ: ERII).

- **Lisa Sorgini, VP Marketing and Strategy**: Ms. Sorgini joins Oasys from Siemens Water Technologies where she served as the Global Director for Municipal Strategic Marketing.

- **Joe Zuback, Senior Advisor, Strategy**: Mr. Zuback has thirty-five years experience in water across municipal, industrial, commercial, residential and wastewater treatment markets. Formerly he was CTO and Senior Vice President for Siemens Water.

- **Dr. Menachem Elimelech, Chair of the Scientific Advisory Board**: Dr. Elimelech is co-inventor of the Oasys process, Chair of the Department of Chemical Engineering, Director of Environmental Engineering and Roberto Goizueta Professor of Environmental and Chemical Engineering at Yale University.

# Oasys Scientific Advisory Board

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

**Dr. Menachem Elimelech – SAB Chairman, Dept Chair of Chemical Eng, Yale University**

3 yr funded research to determine optimal membrane design and draw solution interaction

**Dr. Ingo Pinnau - Director of the Membrane Research Center, KAUST**

FO membrane design

**Dr. Tzahi Cath - Professor of Environmental Science and Engineering, Colorado School of Mines**

Design of FO/PRO systems and 3rd party testing

**Dr. Frank Seibert – Director of AiChE Separations Division, University of Texas**

Distillation column design and 3rd party verification of test results

**Dr. Eli Gal - Independent Consultant**

Distillation system design and heat integration, SRI program coordinator

**Dr. Winston Ho – Professor of Chemical and Biomedical Engineering, Ohio State**

Membrane and Separation Processes