GE GHG ECOMAGINATION INNOVATION CHALLENGE

SUMMARY OF WINNING SUBMISSIONS FOR PHASE 1

Background: The most common recovery process employed for producing from oil sands reservoirs is known as SAGD. In this process, steam is generated at a Central Processing Facility (CPF), transported to well pads, and injected below ground into a horizontal well bore within the reservoir. The heat supplied by the steam warms the heavy oil in the reservoir allowing it to flow via gravity drainage into a second underlying wellbore that captures the oil/water mixture and produces it to the surface.

Once at the surface, the mixture of oil and water is cooled prior to separation. Once separated, the produced water is treated and recycled for steam generation. The resulting oil is treated and delivered into a pipeline for shipping. This cooling process generates significant amounts of low grade heat at 60-80° C.

The industry is looking to identify technologies that can create value from this by-product by converting it to higher value heat for use either within the CPF or SAGD wellbores, or by converting it to electricity at >10% efficiency rate. Existing technologies to upgrade waste heat are not widely used due to associated high capital expenses. GE is interested in developing a portfolio of waste heat recovery technologies that can provide immediate and long-term operational efficiency and environmental benefits, as well as affording a flexible array of paths for development and eventual deployment.

The following winning submissions to GE's GHG Ecomagination Innovation Challenge provided the most promising opportunities for re-use of low grade heat:

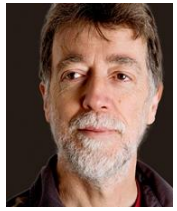
Ammonia/Water Heat Pump

- **Team:** Guha Industries, India. Inventor: Naren Chidambaram
- **Winner profile:** Narendran Chidambaram joined Guha Industries in 1995 and now is the Managing Partner of the company. He has 25 years' rich experience in Process industries which includes process design of membrane

Caustic Soda plant, design of heat exchangers & mass transfer equipment, HAZOP studies, process troubleshooting, project execution and commissioning. Guha Industries executed engineering projects worldwide with a customer-centric approach for over 15 years.

- **Benefit:** This proposal upgrades low grade heat to higher temperature heat which can be applied for use in steam production or power generation. Potential to offset fossil fuel consumption for the production of steam or power, instead using low grade heat.
- **Technology:** Upgraded heat is applied using adsorption refrigeration with an ammonia/water working fluid. The process generates liquid ammonia, and a lean ammonia solution. When the two fluids are pumped to high pressures and recombined, they generate heat at higher temperatures, thus performing as a heat pump. The heat pump is driven by the SAGD low grade heat returned after heat extraction.

Thermoacoustic energy conversion



- **Team:** Aster Thermoacoustics, Netherlands. Inventor: Kees de Blok
- **Winner profile:** Kees de Blok was educated as an engineer in electronics and worked at the R&D institute of the Dutch telecom operator KPN from 1971 until 2000. In 2000 he left KPN and worked full time on thermoacoustics for its own company named Aster Thermoacoustics. He initiated and participated in international projects on thermoacoustics and is also (co) author on various publications and conference proceedings on fibre installation techniques, coherent systems and acoustics and gained various patents on those subjects.
- **Benefit:** This proposal utilizes changes in temperature from low grade heat to produce acoustic waves that can be harnessed to generate power. Potential to offset fossil fuel consumption for power generation, instead using low grade heat.
- **Technology:** Thermoacoustics use a heat difference to induce high-amplitude sound waves. These waves can be used to provide the work required to generate electricity.

Engine for Low Grade Heat

- **Team:** EA Technical Services Ltd., United Kingdom. Inventor: Ron Driver
- **Winner profile:** Ron Driver served an engineering apprenticeship at Rolls Royce and later was employed on research and development solving engine problems. Later he formed Driver Technology Ltd (DTL) to work on new types of compressor and licenced the technology to Honeywell and managed the program. When the Honeywell program ended Ron Driver formed E. A. Technical Services Ltd (EATS) to develop new compressor and turbine technology with financial support from the UK government. The company was also able to get support from The University of Ulster in Northern Ireland and by FT Engineering in England for their work programs.
- **Benefit:** This proposal intends to use low grade heat to produce power for use in the field. Potential to offset fossil fuel consumption for power generation, instead using low grade heat.
- **Technology:** Consists of two cylinders each with an orbiting piston. A heat exchanger captures low grade heat and supplies it to the "hot" piston, driving the flow of air from the "cold" piston to the exchanger. The change in pressure moves the pistons providing useful work.

Opti-Up Heat Pump

- **Team:** Consorzio LEAP, Italy. Inventor: Stefano Consonni (Lead), Manuele Gatti, Emanuele Martelli, Daniele Di Bona, Federico Viganò
- **Winner profile:** Stefano Consonni graduated in Mechanical Engineering at Politecnico di Milano (Polytechnic of Milan) in 1983 and received a M.S. (1987) and Ph.D. (1992) in Mechanical Engineering at Princeton University. He is professor of Energy Systems at Politecnico di Milano in Italy; from 1998 to 2005 Consonni has acted as head of the campus in the city of Piacenza. Since 2005 he is President of LEAP (Laboratory for Energy and the Environment in Piacenza), a consortium promoted by Politecnico di Milano for research and technology transfer on energy and environmental issues.
- **Benefit:** This proposal upgrades low grade heat to higher temperature heat which can be applied for use in steam production or power generation. Potential to offset fossil fuel consumption for the production of steam or power, instead using low grade heat.

- **Technology:** The system is based on a reverse-Rankine cycle, and makes use of a mixture of water and ammonia as the working fluid. The system proposed is a closed-cycle Heat Pump (HP) operating between the heat source and sink. The HP uses electrically driven compressors to upgrade the low grade heat to a higher more useful level.