Tracking the Development of 2nd and 3rd Generation CO2 Capture Technologies

Proposal: CSLF members participate in the creation of a new section of content on the CSLF website

Purpose: To provide a neutral, fact-based information hub for identifying and tracking the progress of 2nd and 3rd generation Co2 capture technologies occurring within CSLF member countries.

carbon sequestration leadership forum

A Global Response to the Challenge of Climate Change

The CSLF is a Ministerial-level international climate change initiative focused on development of technologies for capture and geologic storage of CO2.

- Meetings/Workshops
- Projects
- Publications / Links
- Technology Roadmap
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In The News...

May 22, 2015

Carbon Capture and Storage

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Newswise (press release)-May 21 To their surprise, the researchers found that only 20% of the 1.6 gigatons (a typical coal-fired power plant could emit ~10 to 15 megatons of CO2 per year) of emplaced CO2 have dissolved into the brine over the last million years.

Climate Change

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The Guardian-May 22
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Read more of today's news clips here.

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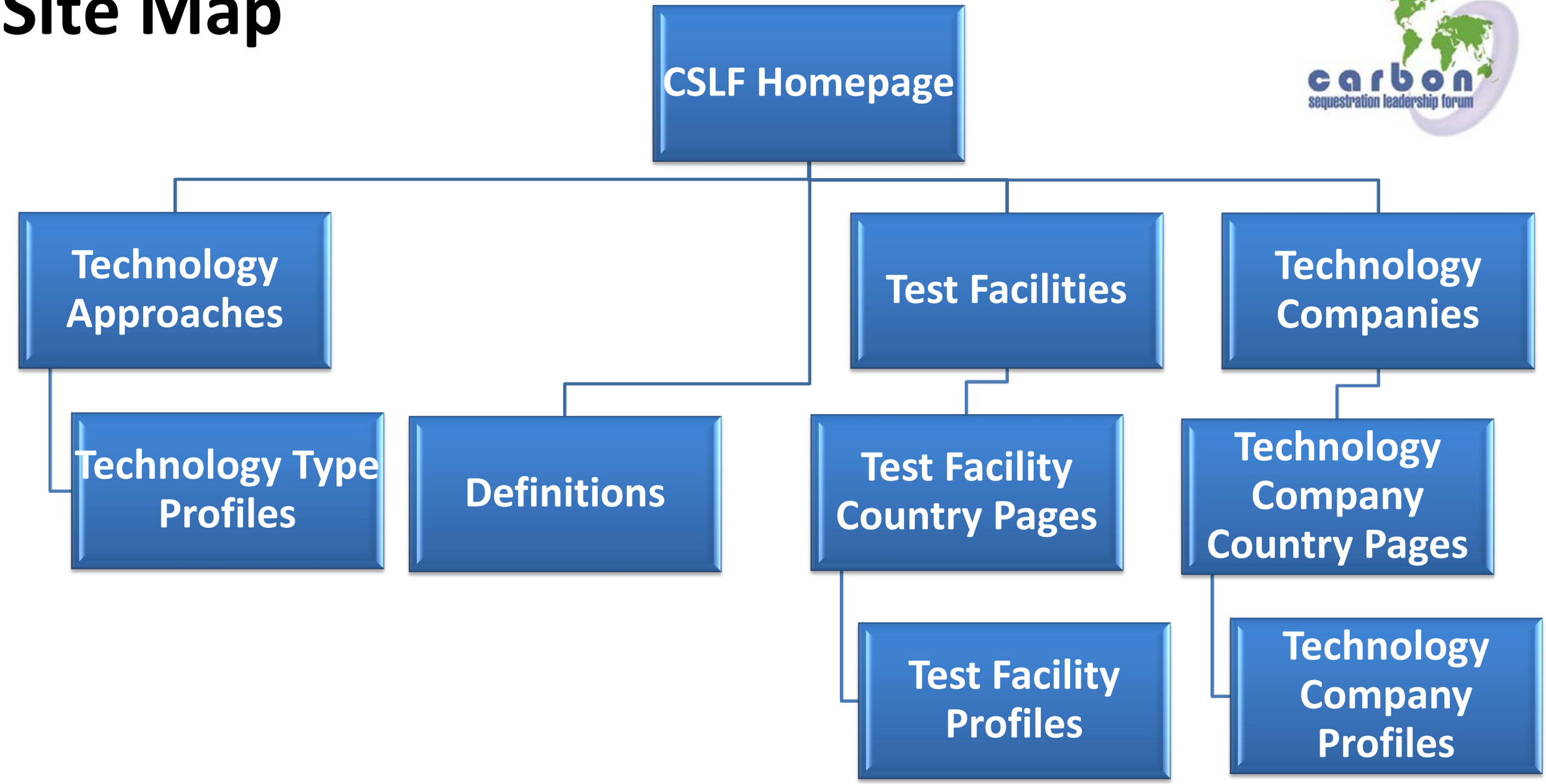
Site Map


CSLF Homepage
Technology Approaches
Test Facilities
Technology Companies
Technology Type Profiles
Definitions
Test Facility Country Pages
Technology Company Country Pages
Test Facility Profiles
Technology Company Profiles

Defining 2nd and 3rd Generation Capture Technologies

What are 2nd 3rd Generation Carbon Capture Technologies?

2nd Generation Technologies include technology components currently in research and development that will be validated and ready for demonstration in the 2020-2025 timeframe.

3rd Generation "Transformational" Technologies include technology components in early development (including conceptual stages) that:

- Offer the potential for significant improvements in technology cost and performance
- Will be ready for scale-up in the 2016-2030 timeframe
- Will be ready for demonstration in the 2030-2035 timeframe

Why is 2nd and 3rd Generation Carbon Capture Technology Development Important?

Carbon capture and storage (CCS) has the potential to prevent significant amounts of carbon from entering the atmosphere. The technology has been demonstrated at both pilot and large-scale across multiple industrial processes. Yet the cost of CCS is one of the most significant barriers to its widespread deployment, with carbon capture accounting for the majority of this cost.

The development of 2nd and 3rd generation carbon capture technologies through research, investment, and demonstration is important for driving down capture technology costs, improving process efficiency, and reducing environmental impacts. Such developments will help to advance the adoption of CCS technologies as part of the global effort to stabilize atmospheric levels of greenhouse gases.

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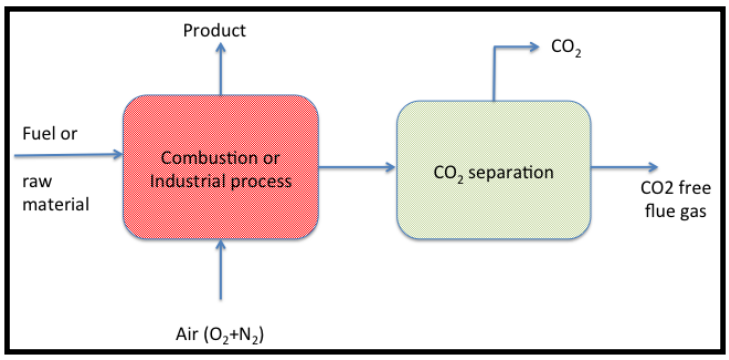
Technology Approaches

Explore types of 2nd and 3rd generation carbon capture CO_2 capture technologies below.

Post-Combustion CO_2 Capture



Post-combustion solvents

- Precipitating solvents
- Two liquid phase solvents
- Enzymes
- Ionic liquids
- Novel solvent systems

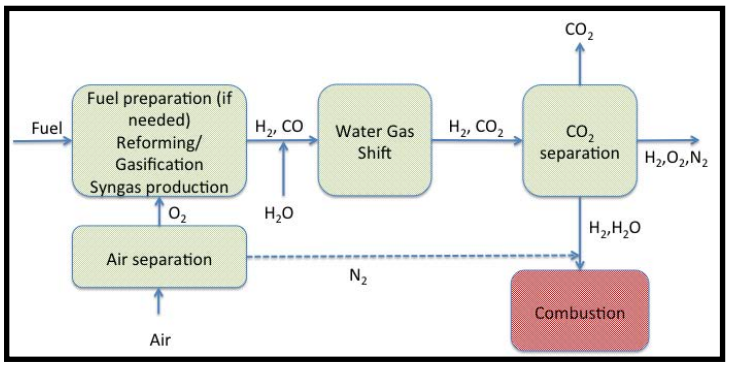
Post-combustion sorbents

- Calcium looping systems
- Other sorbent looping systems
- Vacuum pressure swing adsorption (VPSA)
- Temperature swing adsorption (TSA)

Post-combustion membranes

- Membranes (general)
- Polymeric membranes combined with low temperature separation

Pre-Combustion CO_2 Capture



Pre-combustion solvents

- Pre-combustion solvents

Pre-combustion sorbents

- Sorption-enhanced water gas shift (SEWGS)
- Sorption-enhanced steam-methane reforming (SE-SMR)

Pre-combustion membranes

- Metal and composite membranes
- Ceramic-based hydrogen transport membranes

Low temperature CO2 separation from syngas

- Low temperature CO_2 separation from syngas

Concepts for pre-combustion using fuel cells

- Concepts for pre-combustion using fuel cells

Oxy-Combustion

Chemical looping combustion (CLC)

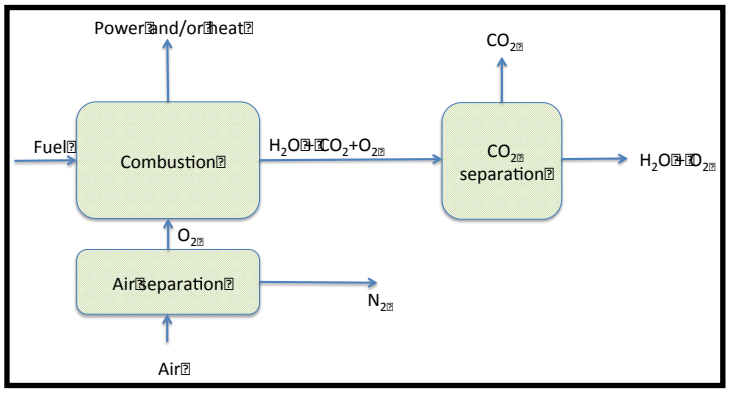
- Chemical looping combustion (CLC)

Oxygen transport membranes (OTM)

- Oxygen transport membranes (OTM)

Oxygen production for oxy-combustion

- O_2 separation membranes
- Cryogenic air separation



Other technologies for improving oxy-combustion

- High-pressure oxy-combustion
- Oxy-combustion gas turbines
- Oxy-combustion boilers
- CO_2 processing and clean-up

Related links

- View companies and test facilities by country
- Find a definition of 2nd and 3rd generation carbon capture technologies

Novel Solvent Systems

Novel solvent systems are 3rd generation carbon capture technologies that aim to minimize the disadvantages of standard amine systems. The current technology challenge is scaling up from lab-scale demonstration.

About Novel Solvent Systems

These are processes that use amine-based solvents with novel system designs that should minimize the known disadvantages of standard amine systems. This can be done through solvent development and/or novel process configurations. Two examples are encapsulated solvent and electrochemically-mediated amine regeneration systems.

Encapsulated solvent involves encapsulating the solvent, e.g. an amine or a carbonate, in thin polymeric membrane or shell, forming beads of size 200 – 400 µm, thereby given a large increase in contact surface area between flue gas and solvent. The inner solvent will perform the selectivity role. The shell must be highly permeable to carbon dioxide and strong enough to survive capture, and presumably release pure CO2 via heating, over thousands of cycles. With the capacity of liquids and the physical behaviour of solid sorbents, encapsulated solvents may be useful in both conventional-style capture applications, as well as new approaches. The liquid, as well as any degradation products or precipitates, remains encapsulated within the beads.

In **electrochemically-mediated amine regeneration (EMAR) systems**, the heat exchanger and stripper is replaced with an electrochemical cell. As integration is required with the plant steam cycle this concept offers the advantage of easier retrofitting than traditional amine or other solvent systems. It may also achieve lower CO2 lean loading. The process has potential to improve the overall process economics by reducing absorber size and lowering system energy penalty.

Maturity

- 3rd generation; TRL 1 - 2 (Encapsulated solvents: Proof of concept; Electrochemically-mediated amine regeneration: Bench to lab scale testing)

Challenges

- Scale-up from lab

Some players

- **Encapsulated solvents:** Lawrence Livermore National Laboratory, University of IL Urbana-Champaign, Babcock and Wilcox Co.
- **Electrochemically-mediated amines:** Mass. Institute of Technology, Siemens, Topchiev Institute of Petrochemical Synthesis, Russia
- **Addition of organic acid:** NTNU

Technology Companies

- **HTC CO2 Systems** is currently applying its LCDesign™ technology and Delta Purification System™ technology at Husky Energy's Pikes Peak South heavy oil facility in Lashburn, Saskatchewan. The pilot project is expected to begin by July 1, 2015. Read more.

Pathway to technology qualification

- On-site testing with real flue gas at e.g. a few tenths of tonnes of CO2/hour
- The impact of SO2 and NOX and the need for reclaiming of solvent needs further investigation
- Further research on packing materials and optimization of liquid/gas ratios is recommended

Infrastructure required

- The concept can utilize the existing infrastructure for post-combustion as found at many larger test facilities i.e. access to real flue gas, water, electricity and other utilities
- Some modifications will be required, such as cathodic systems
- Sufficient electricity must be secured

Environmental impact

- For the encapsulated solvent concept, leakage of amines degradation to the surroundings may be reduced if the encapsulated amines remain structurally intact. This will require further research.
- In general, an improved efficiency may reduce the environmental foot-print.

Applications

- Power industry
- Cement industry
- EMAR also steel and aluminum

Related Links

- Learn about other 2nd and 3rd generation CO2 capture technologies.
- View test facilities and technology companies developing 2nd and 3rd generation carbon capture technologies by country

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Test Facilities and Technology Companies

Choose a CSLF country below to explore profiles of test facilities and technology companies involved in 2nd or 3rd generation carbon capture technologies.

Test Facilities

- Canada
- China
- France
- Germany
- Italy
- Japan
- Korea
- Norway
- United States
- European CO_2 Capture and Storage Laboratory (ECCSEL)
- International CCS Test Centre Network (TCN)

Technology Companies

- Australia
- Brazil
- Canada
- China
- France
- Germany
- Greece
- India
- Italy
- Japan
- Korea
- Mexico
- Netherlands
- New Zealand
- Norway
- Poland
- Russia
- Saudi Arabia
- South Africa
- United Arab Emirates
- United Kingdom
- United States

Related Links

- View technology approaches to 2nd and 3rd generation CO2 capture
- Find a definition of 2nd and 3rd generation carbon capture technologies

Canadian Test Facilities

Explore the profiles below of Canadian-based test facilities for carbon capture technologies.

Test Facilities

- **CanmetENERGY: CCS Pilot-scale Test Facility** (Ottawa, Ontario, Canada) is a Government of Canada facility designed to test and demonstrate pre-combustion, oxy-combustion and solid-based post combustion carbon capture technologies in conjunction with CO_2 storage research. Read more.

- **Husky Energy: Pikes Peak South CO2 Capture Technology Research & Development Facility** (Lashburn, Saskatchewan, Canada) provides technology developers with an opportunity to test carbon capture technologies. The facility's first and second pilot technology tests will take place in the 2015 – 2016 timeframe. Read more.

- **SaskPower: Carbon Capture Test Facility** (Estevan, Saskatchewan, Canada) is designed to allow companies from around the world to develop and test their next generation of CCS technology. Mitsubishi Hitachi Power Systems (MHPS), Ltd. will use the facility throughout 2015 and 2016 to evaluate their carbon capture system. Following MHPS, the facility will host other technologies. Read more.

Related Links

- Learn about Canadian companies
- Explore technology companies and test facilities based in other CSLF countries
- Find a definition of 2nd and 3rd generation carbon capture technologies
- View technology approaches to 2nd and 3rd generation CO2 capture

Husky Energy: Pikes Peak South CO_2 Capture Technology Research & Development Facility

Located near Lashburn, Saskatchewan, Canada, Husky Energy's Pikes Peak South CO_2 Capture Technology Research & Development Facility provides technology developers with an opportunity to test carbon capture technologies. The facility's first and second pilot technology tests will take place in the 2015 – 2016 timeframe.

About the Test Facility

The test facility is adjacent to Husky's Pikes Peak South heavy oil thermal project.

Aerial view of Pikes Peak South heavy oil thermal facility
Courtesy: Husky Energy

The facility provides developers with an opportunity to test carbon capture technologies for use in industrial exhaust emissions applications. It provides plot space and CO_2 from the exhaust of a 50-MMBtu/hr Once-Through Steam Generator. The Pikes Peak complex offers supporting utilities, including: fuel gas, softened water, electricity, instrument air, water disposal capacity, and is close to the City of Lloydminster, which offers local construction support services. The facility is designed to use captured CO_2 for enhanced oil recovery in a nearby reservoir.

Test Facility Status

Commissioning of the Pikes Peak South CO_2 Capture Technology Research & Development Facility is underway. The first pilot technology tests are expected to begin in the third quarter of 2015. A second technology will be tested in the second quarter of 2016. Connections from the R&D facility to Husky's heavy oil operations and space for future technology testing will be available after initial pilot testing is completed in 2016.

Performance Results

- Initial pilot testing will take place in the 2015 – 2016 timeframe

Partners & Funding

Funding: $2,955,000
Partners: Climate Change and Emissions Management Corporation (CCEMC)

Funding: $3,000,000
Partners: Saskatchewan Petroleum Research Incentive (SPRI)

Learn More

- Contact Husky Energy
- Learn more about Husky Energy

SaskPower: Carbon Capture Test Facility

Located at the coal fired Shand Power Station near Estevan, Saskatchewan, Canada, SaskPower's Carbon Capture Test Facility (CCTF) is designed to allow companies from around the world to develop and test their next generation of CCS technology. Mitsubishi Hitachi Power Systems (MHPS), Ltd. will use the facility throughout 2015 and 2016 to evaluate their carbon capture system. Following MHPS, the facility will host other technologies.

About the Test Facility

The test facility will provide a robust evaluation of technology-specific performance parameters such as collection efficiency, long-term stability, operability, maintainability and reliability of post-combustion capture systems. The facility can accommodate a wide range of solvents, processes and system configurations.

Shand Carbon Capture Test Facility (CCTF) - Estevan, Saskatchewan, Sept 2014
Photo Credit: SaskPower

The CCTF has been designed to provide a high degree of certainty on performance measurement while respecting the costs which come with operating and adjusting very large-scale pilot systems. With its two meter diameter multi bed absorber, remaining uncertainty in measurements such as Effective Mass Transfer Coefficient is below the threshold of typical commercial performance guarantees. Yet changing absorber components to suit an alternative process arrangement remains a practical option for future tests.

The close connection to the Boundary Dam CCS project means that technologies tested at CCTF can also benefit from valuable large-scale commercial experience.

Test Facility Status

As of June 2015, construction and commissioning of the CCTF is complete. SaskPower is awaiting final checks from MHPS before loading amine into the process.

Construction of the CCTF began in 2013.

Performance

- **CO_2 Capture:** at design conditions the CCTF will capture and release about 120 Tonnes per day of CO_2

- **SO_2 levels:** ability to control SO2 concentration to less than 1 ppm at absorber inlet has been confirmed
- All **flue gas pretreatment systems:** have been tested and shown to operate at or better than design
- Performance details of **MHPS's technology** will be proprietary information of MHPS

Partners & Funding

- Natural Resources Canada provided approximately $1 million under its ecoEnergy Technology Initiative to support preliminary engineering
- The remaining project cost (approximately $70 million) was shared between SaskPower and Mitsubishi Hitachi Power Systems

Learn More

- Contact SaskPower
- Find out more about SaskPower's Carbon Capture Test Facility
- Learn more about SaskPower

Test Facilities and Technology Companies

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- Saudi Arabia
- South Africa
- United Arab Emirates
- United Kingdom
- United States

Related Links

- View technology approaches to 2nd and 3rd generation CO2 capture
- Find a definition of 2nd and 3rd generation carbon capture technologies

Canadian Companies

Explore the profiles below of Canadian-based companies currently developing 2nd or 3rd generation carbon capture technologies.

Companies

- **Carbon Engineering** is currently operating a demonstration plant of its air capture technology in Squamish, British Columbia. The demo plant is set to run from June-November 2015, and will deliver CE the performance data needed to engineer a subsequent full commercial plant. Read more.

- **CO_2 Solutions** is testing its enzyme-enabled CO_2 capture technology in a field pilot in Salaberry-de-Valleyfield, Quebec, Canada, in collaboration with Husky Energy Inc. The pilot project was commissioned in May 2015. Read more.

- **HTC CO2 Systems** is currently applying its LCDesign™ technology and Delta Purification System™ technology at Husky Energy's Pikes Peak South heavy oil facility in Lashburn, Saskatchewan. The pilot project is expected to begin by July 1, 2015. Read more.

- **Inventys** is testing its VeloxoTherm™ technology in pilot plant demonstration projects, including a field project near Lloydminster, Saskatchewan to be completed in 2017. Read more.

- **Shell Cansolv** offers CANSOLV SO2/CO2 Integrated Capture System technology – an integrated system that uses the same technology to sequentially scrub SO_2 and CO_2. The technology is currently in operation at SaskPower's Boundary Dam Power Station near Estevan, Saskatchewan. Read more.

Related Links

- Learn about Canadian test facilities
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HTC CO2 Systems Corp.: LCDesign™ & Delta Purification System™

HTC CO2 Systems Corp. is currently applying its LCDesign™ technology and Delta Purification System™ technology at Husky Energy's Pikes Peak South heavy oil facility in Lashburn, Saskatchewan. The pilot project is expected to begin by July 1, 2015.

About the Technology

LCDesign™

HTC CO_2 Systems Corp. has engineered and designed a post combustion CO_2 Capture system brand named LCDesign™ (Low Cost Design). Using oil field modular manufacturing and delivery techniques, the system uses a proprietary mixed amine solvent blend to absorb CO_2 from a plant's flue gas before it is emitted into the atmosphere. The design is based on efficient process configuration, a low energy solvent, and optimum operating parameters.

HTC LCDesign™ CO_2 capture system located at Husky Energy's Pikes Peak South heavy oil facility in Lashburn, Saskatchewan.

Delta Purification System™

HTC CO_2 Systems Corp. has also developed a new patented solvent/glycol reclaiming system that manages the solvents that are used to absorb CO_2 in post-combustion carbon capture. Called the Delta Purification System™, the system aims to optimize solvent performance by removing impurities from mixed and formulated solvents used to capture CO_2 and H_2S. The Delta Purification System™ also purifies the glycols used to remove impurities, such as water, to meet natural gas pipeline specifications.

Technology Status

HTC CO_2 Systems Corp. is currently commissioning a pilot project to apply both its LCDesign™ technology and Delta Purification System™ technology at Husky Energy's Pikes Peak South heavy oil facility in Lashburn, Saskatchewan. A LCDesign™ CO_2 capture unit has been installed at the facility. The unit will process 50% of the flue gas from a Once Through Steam Generator ("OTSG"), a natural gas-fired boiler that generates steam, capturing 30 tonnes of CO_2 per day. The captured CO_2 will be utilized to increase heavy oil production through enhanced oil recovery techniques. The pilot project is expected to begin operation by July 1, 2015.

Performance Results

- **In initial engineering assessments:** A Front End Engineering and Design (FEED) study was completed to assess the cost of capturing 1000 tonnes per day of CO_2 from the flue gas of three OTSGs at Devon Energy's Jackfish-1 thermal in-situ operations in Alberta. Read the results.
- **In Pilot testing:** Performance results of the pilot project at Husky Energy's facility will be announced after the project is completed.

Partners & Funding

Funding
Husky Energy's Pikes Peak South project is funded by:

- Alberta's Climate Change and Emissions Management Corporation (CCEMC)
- The Government of Saskatchewan
- Husky Energy

Partners
HTC CO2 Systems has two licensing partners:

- Doosan Power systems (South Korea)
- ASCO Carbon Dioxide ltd. (Germany)

Learn More

- Contact HTC CO2 Systems
- Find out more about Delta Purification System Technology
- Find out more about LCDesign™
- Read a feature about HTC's technology in the Carbon Capture Journal (May / June 2015 edition)
- Learn more about HTC CO2 Systems

Related Links

- Find out more about novel solvent system technologies

Inventys: VeloxoTherm™

Inventys is testing its VeloxoTherm™ technology in pilot plant demonstration projects, including a field project near Lloydminster, Saskatchewan to be completed in 2017.

About the Technology

VeloxoTherm™ is carbon capture in 60 seconds. It's the world's first post-combustion CO_2 capture process using structured adsorbents within an intensified thermal swing adsorption process. This unique approach, which capitalizes on a 60-second cycle, offers advantages over conventional methods including lower capital and operating costs.

The VeloxoTherm™ demonstration unit, with all the features of a full plant, supports continuous quality-characteristic testing for endurance and reliability. Photo Credit: Inventys

Technology Status

Inventys has a CO_2 capture process demonstration unit, with all the features of a full plant, operating in its facilities. The unit supports continuous quality characteristic testing for endurance and reliability, which is currently focused on verifying mechanical and process performance. Inventys is working on pilot plant demonstration projects to test its VeloxoTherm™ technology for commercialization.

Performance Results

- **Through Demonstration Unit Testing:** Inventys estimates VeloxoTherm's CO_2 capture cost to settle at one-third the cost of current methods. This is corroborated through a third-party engineering firm's evaluation and extensive ongoing testing of various scales of hardware and process requirements.

Partners & Funding

Equity Investors

- Chevron
- Mitsui Global Investment (MGI)
- The Roda Group
- Chrysalix Energy Venture Capital

Public and Project Funding

- Husky Energy
- Suncor Energy

- Climate Change and Emissions Management Corporation (CCEMC)
- Sustainable Development Technology Canada (SDTC)
- Energy Technologies Institute (ETI)
- Industrial Research Assistance Program (IRAP)

Learn More

- Contact Inventys
- Find out more about VeloxoTherm
- Learn more about Inventys

Related Links

- Find out more about temperature swing adsorption (TSA) technologies

Seeking Your Input

Member Input:

- Test Facilities
- Technology Companies

Audience:

- Technology developers/adopters
- Specialized public (i.e. investors / governments /educators / media)

Value:

- Appropriate path forward?
- Appropriate exposure?
- Additional ideas?