Making Natural Gas a Lower Emission Energy Source

Dalhousie University — Inspiring Minds

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I. Introduction

With Canada's projected increase in energy demand (Fig.1) combined with government's goal of continually reducing Greenhouse Gas (GHG) emissions (Fig.2), energy production must become more efficient. In the next 20 years, renewable energy sources will not be able to completely replace fossil fuel future demand due to technological restrictions (eg. storage issues and intermittent energy production). Other energy sources are needed. Natural gas, the cleanest burning fossil fuel, combined with Carbon Capture and Storage (CCS) provides a fuel source that will meet future energy demands while reducing GHG emissions.

Need to Reduce Emissions

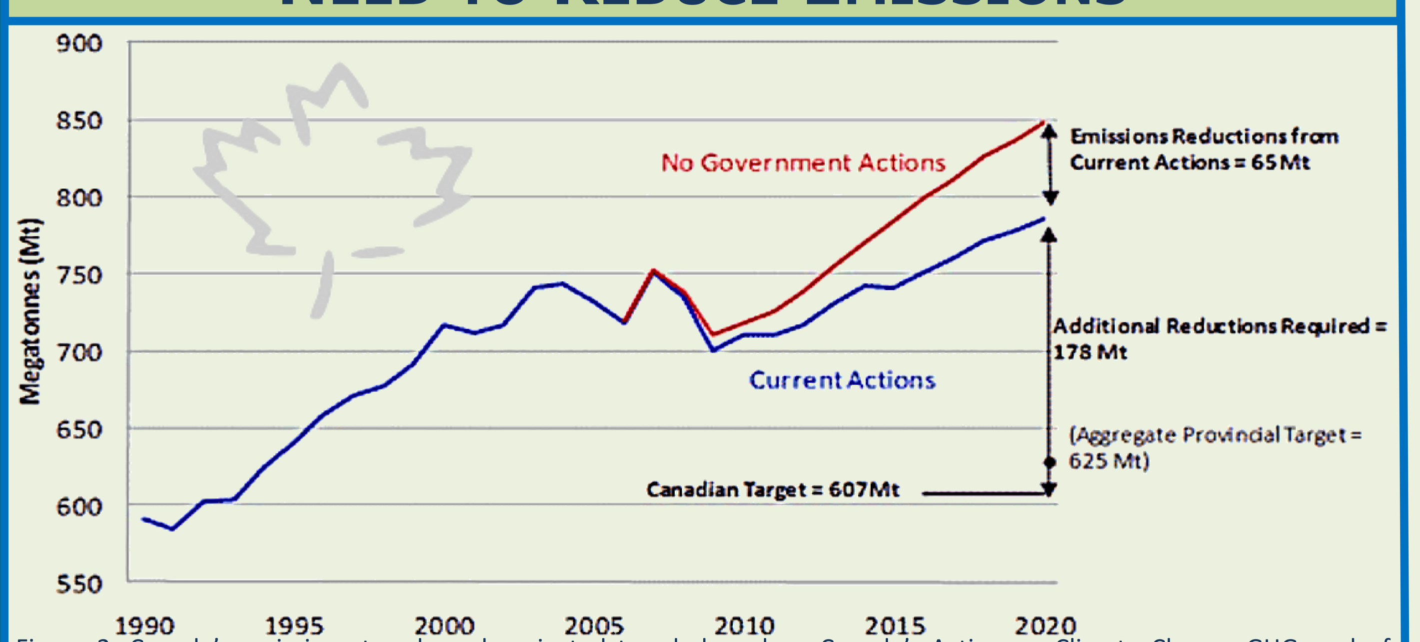


Figure 2: Canada's emissions trends and projected trends based on Canada's Action on Climate Change GHG goal of reducing total emissions by 17% from the 2005 levels by 2020 (decrease to 607Mt) (Environment Canada, 2011). World wide, emission reduction targets are set based on stabilizing atmospheric concentrations of carbon dioxide equivalents leading to a global average temperature increase above pre-industrial levels of 2.0-2.4°C (Soloman et al., 2007). CCS is expected to account for 17% of the global emission reductions and fuel switching (coal to natural gas) is expected to account for 12% (IEA, 2013).

Increasing Energy Demand

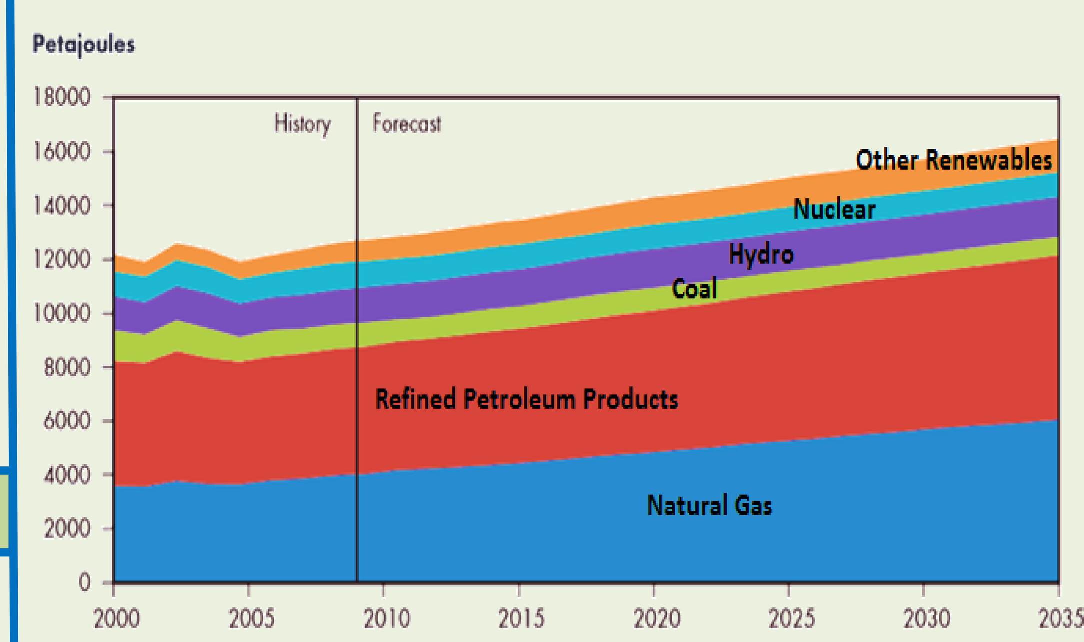


Figure 1: Canada's Primary Energy Demand by Fuel (National Energy Board, 2011)

In Canada, annual energy demand is expected to increase 1.2% (Fig.1). This rate has decreased over time, but still results in an absolute increase in energy demand. Although renewable energy sources have the largest projected rate of increase they still represent a small portion of the total energy supply while fossil fuels make up the majority of the supply (Fig.1). Natural gas is expected to have the second highest demand increase with 1.9% and represents about a third of the total amount of fuel consumed (Fig.1).

II. Natural Gas Supply & Combustion Properties

Due to recent increases in unconventional natural gas production in North America, particularly the United States (Fig.3), natural gas has become an abundant domestic energy source with production projected to increase (in the US) and remain constant (in Canada) through to 2035.

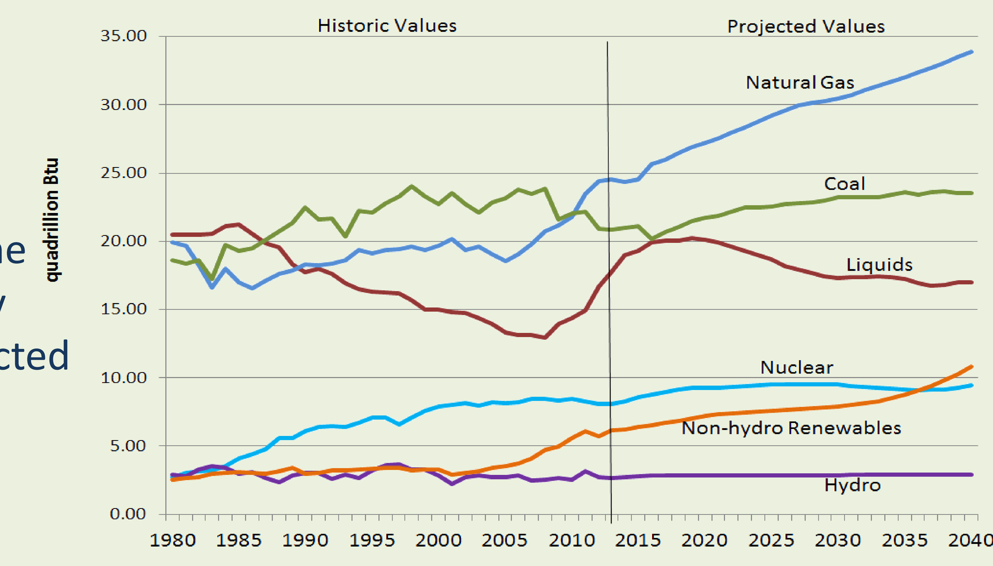


Figure 3: US energy production projections by Fuel (Modified from: US EIA, 2013).

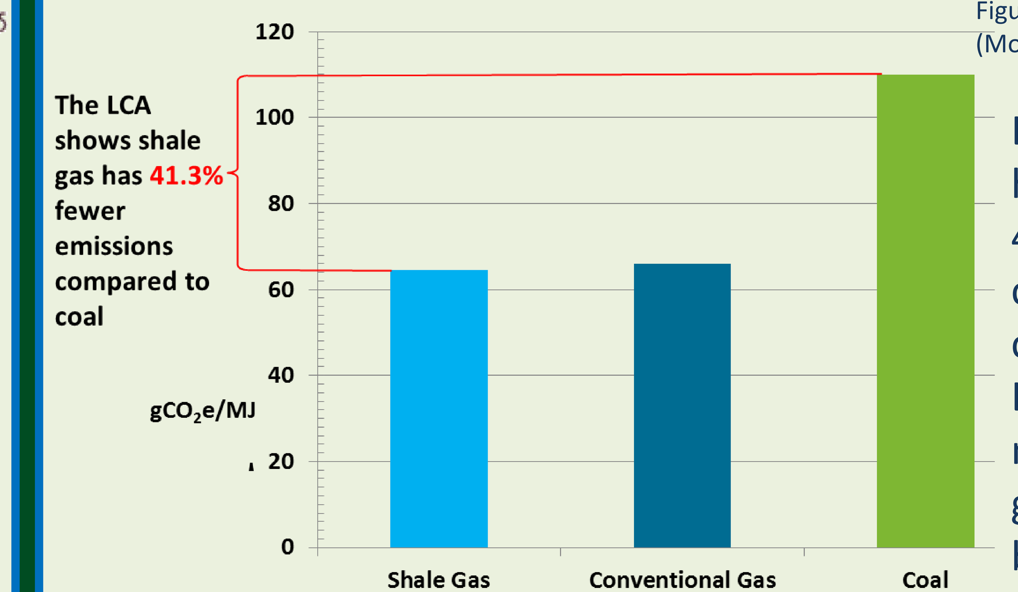


Figure 4: LCA of natural gas from conventional and unconventional sources compared to coal (Modified from: Weber & Clavin, 2012 and Cathles et al., 2012).

Life Cycle Analysis (LCA) studies have found that shale gas has 41.3% fewer emissions compared to coal (Fig.4) due to cleaner burning natural gas. LCA takes into consideration methane leakage from natural gas operations and mitigation best practices.

III. Life Cycle Analysis of Natural Gas

Natural gas is the cleanest burning fossil fuel but emissions must be further reduced to reach GHG reduction targets. LCA show emissions associated with natural gas are a fraction of the associated coal emissions but LCA also indicates what stage has the most potential for improvement throughout the life cycle of natural gas. Areas of highest potential improvement are:

1. Electricity production (~76% of total emissions, Fig.5)
2. Methane leakage (~13.5% of total emissions, Fig.5)

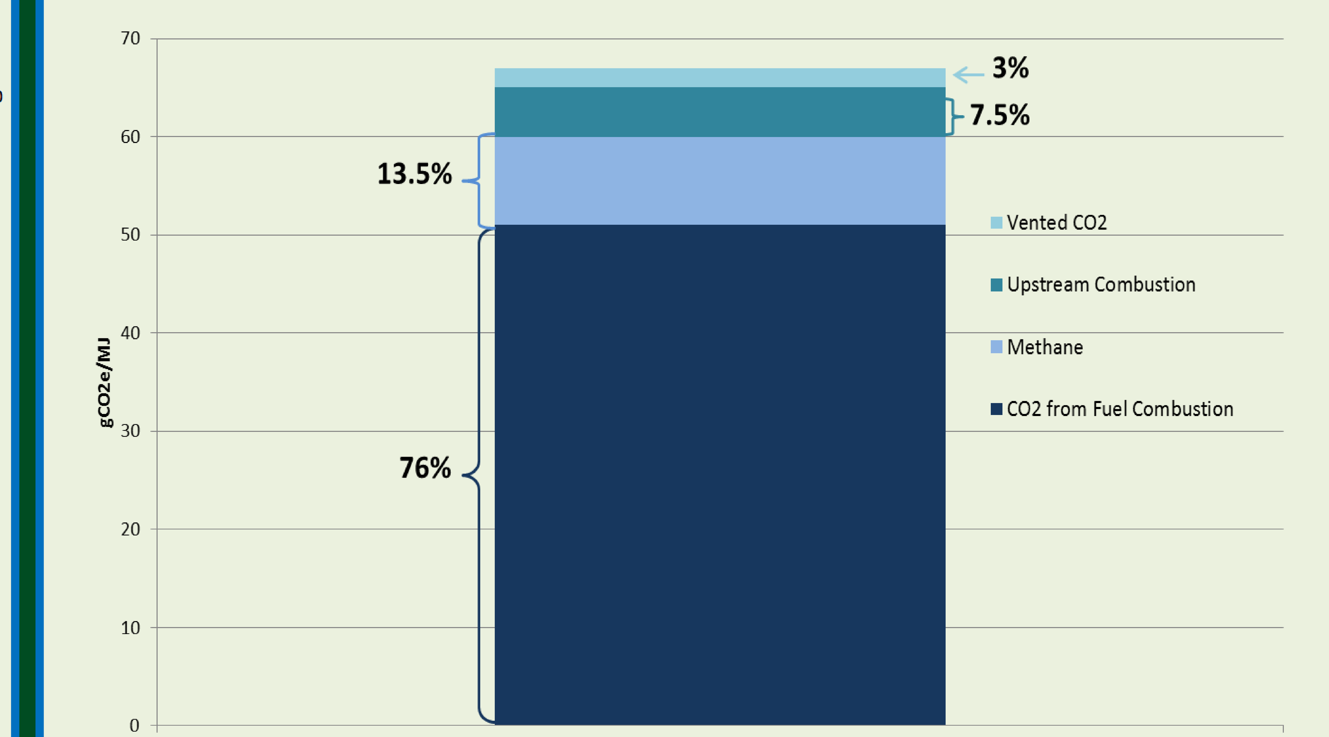


Figure 5: Emissions LCA breakdown of natural gas as an energy source (Modified from: ICF consulting Canada, 2012 and Jiang et al., 2011).

IV. Electricity Production Improvements: CCS

Natural Gas-Fired Electricity CO_2 Emissions: Scale of the Problem

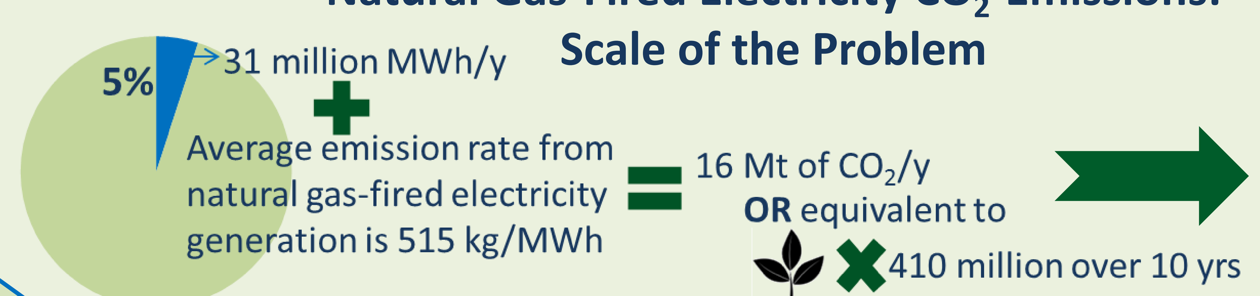
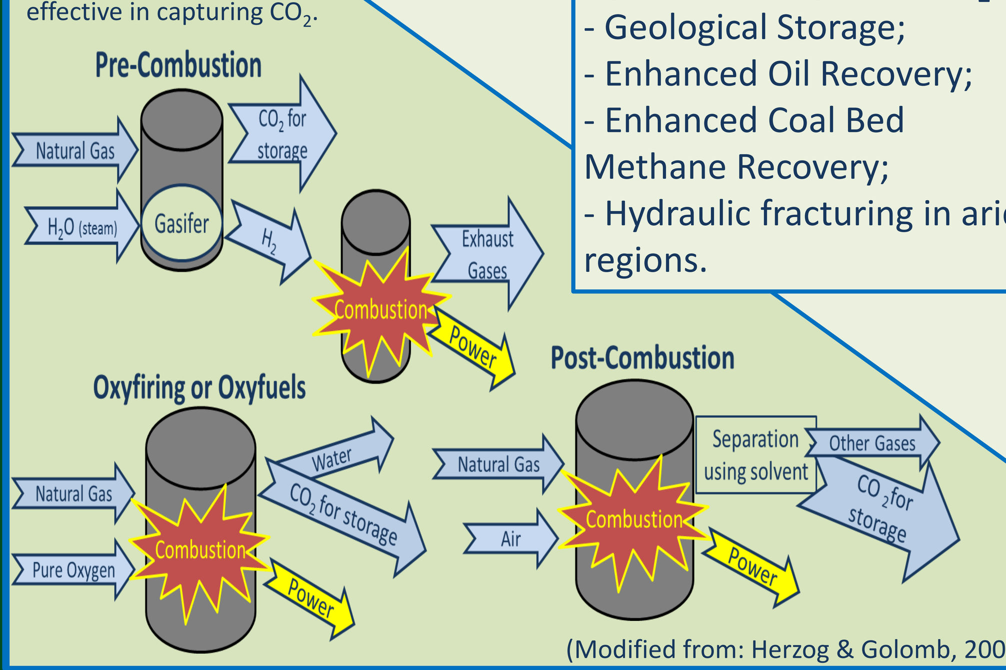


Figure 6: Canada currently produces 5% of its electrical energy using natural gas-fired power plants. These plants emit approximately 16 Mt of CO_2 which is equivalent to the amount of carbon sequestered by 410 million seedlings over 10 years (EPA, 2012 & Environment Canada, 2011).

Solution: There is 16Mt of potential CO_2 to capture from concentrated sources (power plants) in Canada. Pairing efficient natural gas power plants with CCS technology will help bridge our growing demand for energy while reducing GHG emissions.

CO_2 Capture:

Methods are 99% effective in capturing CO_2.



(Modified from: Herzog & Golomb, 2004 and CO2CRC, 2013)

Options for Captured CO_2:
- Geological Storage;
- Enhanced Oil Recovery;
- Enhanced Coal Bed Methane Recovery;
- Hydraulic fracturing in arid regions.

Geological Storage:

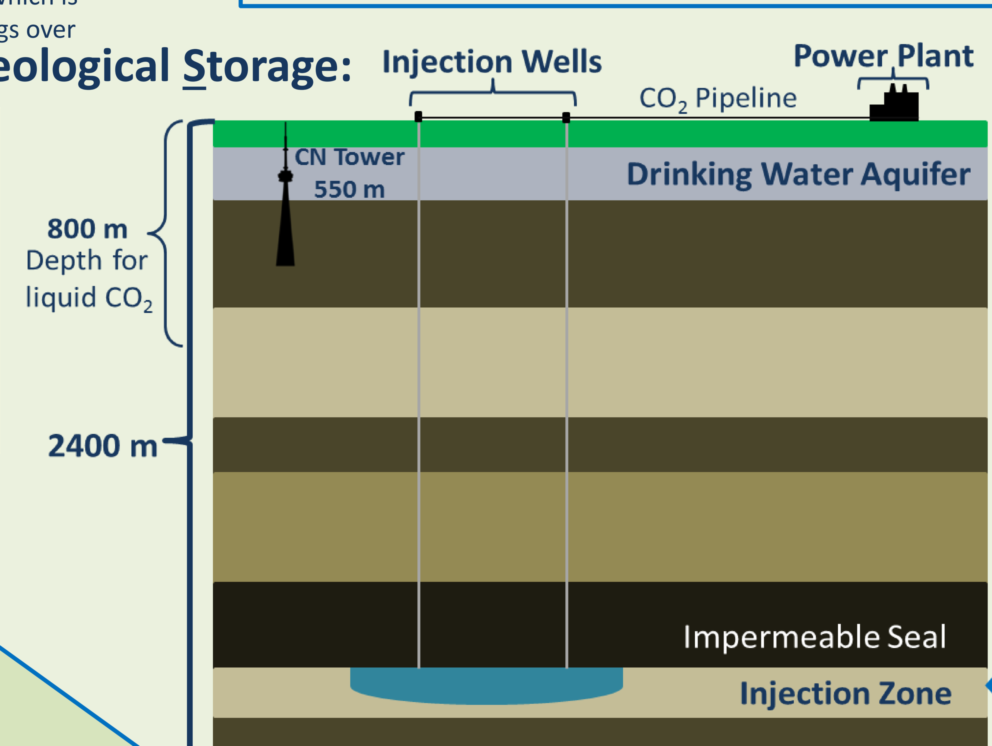


Figure 7: CCS Schematic (Modified from: EPA, 2012)

Injection Zone:
- High porosity & permeability e.g. depleted oil or gas reservoirs or deep saline formations

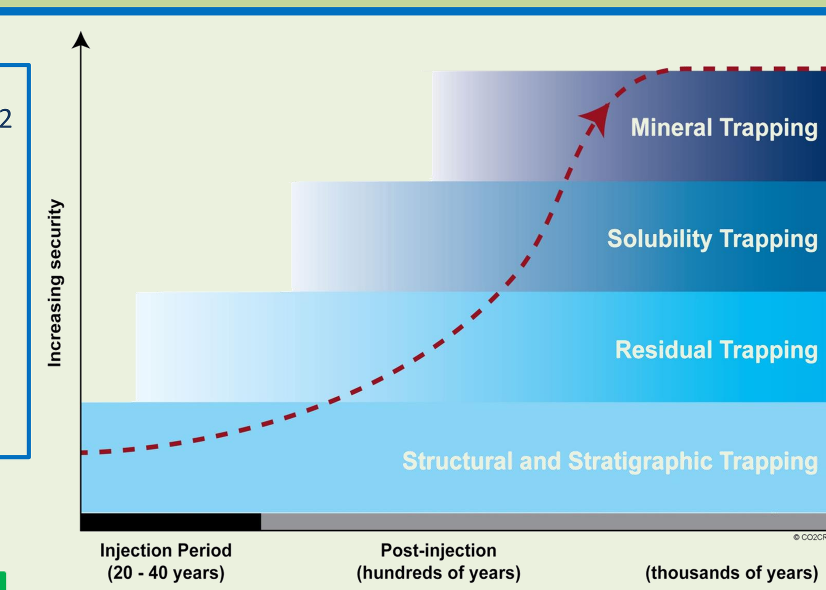


Figure 8: Trapping mechanisms for geological storage of CO_2. (Cooperative Research Centre for Greenhouse Gas Technologies, 2013).

Once CO_2 is injected **Trapping Mechanisms** (Fig.8) inhibit CO_2 migration outside of the target reservoir. Initially, only structural and stratigraphic trapping occur but over time trapping security increases (Fig.8).

V. Methane Leak Improvements

Reduced Emissions Completions (RECs) is the act of capturing gas produced during hydraulic fracturing well completions. Methane leakage from the wellhead, could jeopardize the emission benefits of natural gas compared to coal, as methane has a higher global warming potential than CO_2. When REC equipment is used (Fig.9), upstream emissions can be reduced by 13% (Weber & Clavin, 2012).

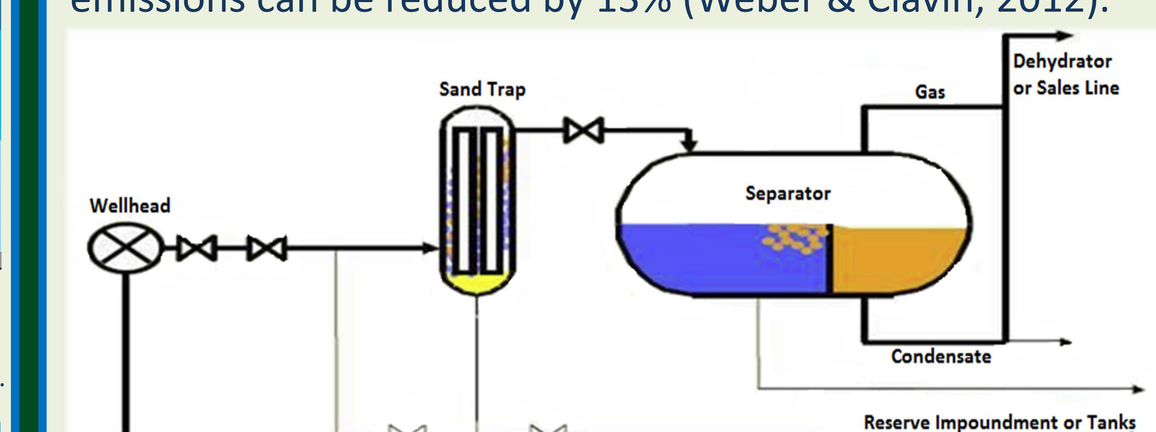


Figure 9: Reduced Emissions Completions Equipment Layout (EPA, 2011)

VI. Conclusions

1. With higher demands for energy North America needs energy sources with fewer emissions. Although renewable resources are an important component of clean energy strategy, they are not fully developed as a baseload energy source. Their intermittent nature (particularly wind and solar) require a dependable, continuous energy source.

2. Natural gas is an abundant, cheap, domestic energy resource and is significantly cleaner than coal or oil. CCS and fuel switching to natural gas will provide a transitional energy resource as the conversion from fossil fuels to renewable energy occurs.

Recommendations

Carbon Capture: As coal-fired power plants age, replace with efficient natural gas-fired plants. New and current natural gas-fired power plants should be designed or retrofitted to be carbon capture ready.

Storage: Where geology allows, storage should be put in place. In places where geology is not suitable pipelines will be needed to transport CO_2.

Methane: Improvements in well completion technology needs to be reflected in regulations to ensure methane leakage is mitigated.

Overall: Government incentive/support should be provided to ensure CCS is implemented on a broad scale.

References

Alvarez, R., Pacala, S., Winebrake, J., Chameides, W., Hamburg, S. (2012). Greater focus needed on methane leakage from natural gas infrastructure. *Proceeding of the National Academy of Sciences, 109* (17), 6435-6440.

Bullis, K. (2013). Skipping the water in fracking. MIT technology. Retrieved from: www.technologyreview.com

Burnham et al. (2012). life-cycle greenhouse gas emissions of shale gas, natural gas, coal, and petroleum. *Environmental Science & Technology*, 46, 619-627.

Cathles, L., Brown, L., Taam, M. & Hunter, A. (2012). A commentary on "The greenhouse-gas footprint of natural gas in shale formations" by R.W. Howarth, R. Santoro, and Anthony Ingraffea. *Climate Change*, DOI 10.1007/s10584-011-0333-0.

Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC). (2013). About CCS. Retrieved from: www.co2crc.com

Environment Canada. (2011). Canada's Emission trends. Retrieved from: www.ec.gc.ca

Environmental Protection Agency (EPA). (2011). Reduced Emissions Completions for Hydraulically Fractured Natural gas Wells.

EPA. (2012). Natural gas: Electricity from natural gas. Retrieved from: www.epa.gov

Fulton, M., Mellquist, N., Kitasei, S., Bluestein, J. (2011). Comparing life-cycle greenhouse gas emissions from natural gas and coal. Worldwatch Institute.

Hartling, A. (2008). Carbon Capture and Storage in British Columbia. Geoscience Reports: *BC Ministry of Energy, Mine and Petroleum Resources*, 25-31.

Herzog, H., Golomb, D. (2004). Carbon capture and storage from fossil fuel use. *Encyclopedia of Energy,* 277-287.

ICF Consulting Canada. (2012). Life cycle greenhouse gas emissions of natural gas. The Canadian Natural Gas Initiative (CNGI).

Institution of Mechanical Engineers (2010). Carbon Capture and Storage: Natural Gas Power Plants. Retrieved from: www.imeche.org

Integrated CO2 Network. Canadian Carbon Capture and Storage Projects. Retrieved from: http://www.ico2n.com

International Energy Agency (IEA), 2013. Emission Reductions. Retrieved from: http://www.iea.org

Jiang et al. (2011). Life cycle greenhouse gas emissions of Marcellus shale gas. *Environmental Research Letters* DOI 10.1088/1748-9326/6/3/034014.

Miller, J. (2013). Is Natural Gas Critical to reduce US Carbon Emissions? The Energy Collective. Retrieved from: www.thenergycollective.com

National Energy Board. (2011). Energy Futures backgrounder: Addendum to Canada's Energy Future: Energy Supply and Demand Projections to 2035. Retrieved from: www.neb-one.gc.ca

National Energy Technology Laboratory (NETL), 2010. Carbon Storage FAQ Information Portal. Retrieved from: www.netl.doe.gov

Rubin, E. & Zhai, H. (2012). The cost of carbon capture and storage for natural gas combined cycle power plants. *Environmental Science and Technology*, 46, 3076-3084.

Soloman et al. (2007). IPCC Fourth Assessment report: Climate Change 2007. Working Group I: The Physical Science Basis. Cambridge University Press, Cambridge, United Kingdom.

U.S. Energy Information Administration (EIA), (2013). Annual Energy Outlook 2013 early release Overview. Retrieved from: www.eia.gov

Weber, C. & Clavin, C. (2012). Life Cycle Carbon Footprint of Shale Gas: Review of Evidence and Implications. *Environmental Science & Technology*, 46, 5688-5695.

Acknowledgements

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