GREEN COMMUNITIES CARBON NEUTRAL FRAMEWORK
OPTION 1: PROJECT PROFILE
TRENCHLESS TECHNOLOGY CAPITAL PROJECTS

Project Profile Overview

This project profile provides guidance on estimating the amount of greenhouse gas (GHG) emissions that can be reduced by using a "trenchless technology" for capital projects to upgrade, repair, replace or construct a water or wastewater utility pipe, instead of using conventional open-cut trenching.

In contrast to traditional trenching, which involves digging a trench, hauling extracted material to a disposal site and replacing with new material, trenchless technologies involve drawing a new pipe (or pipe lining) along the path of an existing pipe or boring for new constructions. In turn, it requires removal of less material than conventional trenching, with consequent reductions in diesel fuel consumption and related GHG emissions. GHG emissions have the potential to be significantly reduced by using trenchless technologies instead of conventional trenching. These reductions are dependent on the location of the project and the sites to/from which material is hauled, the type of soil that the utility pipe is in, the number of lateral connections to the pipe and the type of trenchless technology used.

Trenchless technology projects evaluated under this profile will achieve net GHG reduction through a reduction in material excavated and transported, as quantified using the accompanying calculator. This profile will determine the net GHG emissions reduced in tonnes of Carbon Dioxide equivalents (tCO2e).

Most cities in Canada now use trenchless methods for a small part (less than 5%) of their utility construction or re-habilitation program, and eligible projects are expected to reduce carbon emissions compared to the business as usual scenario (cut and cover).

Calculating Emission Reductions

The Excel-based calculator associated with this project profile provides an accounting approach to measuring emissions reductions in the year that they would have occurred. First, the tool calculates the total excavation volumes for open-cut and trenchless scenarios using the dimensions provided by the user, and then calculates fuel use from hauling material to the dumpsite.

The calculator requires inputs for soil type, ground conditions, pipe diameter, pipe length and number of lateral connections. The user may choose to provide inputs for the following parameters (or can allow the tool to use default values): pipe laying depth at start and end, percentage of excavated material reused, dump truck capacity, distance of project site to dump site, number of manholes, number of entry pits, exit pits, and runs, and dimensions of manholes, lateral connections, and entry/exit pits, and open cut trench upper and lower width and productivity (in meters per 8 hour day). If project specific information is available to the user, the tool also allows the user to customize the default inputs of productivity values (in meter per hour progress for each trenchless technology) and also for the power ratings of the machinery used for the project.

Machinery fuel use (and emissions) is calculated by using established engineering productivity data for the project soil type and ground conditions to determine the running time for the equipment used in open cut and the excavation portion of trenchless projects. The tool uses productivity data for the trenchless technology to determine the running time for the trenchless equipment.

The list of equipment for each technology was developed using established references, expert interviews and vetted through an informal peer review process and testing against real project data. Fuel use is calculated by multiplying the running time by the operational horse power (load factor taken into account) by the EPA BSFC kg Fuel/hp-hr. Emissions are obtained by multiplying fuel use by the appropriate emission factor from BC's 2016/17 Best practices methodology for quantifying greenhouse gas emissions.

Project Example

The following example illustrates the steps needed to estimate the Net Emission Reductions associated with using trenchless technology instead of the conventional open-cut trenching approach. This is a hypothetical example meant to illustrate the potential GHG savings from a fictitious project.

In 2015, a local government determines that an old water main needs to be replaced that runs underneath a busy urban road. The options available are to undertake open-cut trenching or to use a trenchless technology. After an evaluation of the different options available, the local government's engineer responsible for the project decides that trenchless pipe bursting will be the best approach to take, in part because of the reduced environmental impact of the approach.

The following describes an example of a **Pipe Bursting** project:

- Soil type: **Medium Soil**
- Ground Conditions: **Wet**
- Surface Type: **Asphalt**
- Pipe Diameter: **375 mm**
- Length: **200 m**
- Pipe Depth at Start: **2.5m**
- Pipe Depth at End: **2.5m**
- Percent of excavated soil reused: **0% (Default)**
- Soil/gravel/sand truck capacity: **7.5 m^3 (Default)**
- Project site to dump site: **10 km (Default)**
- Total number of manholes: **2** ; Length: **2.1 m (Default)**; Width: **2.1 m (Default);** Depth: **2.5 m (Default)**
- Lateral/Service Connections Near-Side: **3**; Length: **3.0 m**; Width: **0.9 m (Default)**; Depth: **2.0 m (Default)**
- Lateral/Service Connections Far-Side: **3**; Length: **5.5 m**; Width: **0.9 m (Default)**; Depth: **2.0 m (Default)**
- Entry Pits: **1 (Default)**; Length: **9.0 m (Default)**; Width: **1.8 m (Default)**; Depth: **2.5 m (Default)**

- Exit Pits: **1 (Default)**; Length: **4.9 m (Default)**; Width: **1.8 m (Default)**; Depth: **2.5 m (Default)**
- Number of runs if applicable: **2 (Default)**
- Trench Upper Width: **1.4 m (Default)**
- Trench Lower Width: **0.9 m (Default)**
- Productivity for open cut section of project: **18.9 m/8hr day (Default)**
- Machinery: All default values for Open Cut without steam boiler and Pipe Bursting done with hydraulic unit

The results of this project were reductions of **45.9 tonnes of CO2e** after a 10% net down of results to account for model and assumption uncertainty. This is equivalent to **15,861 Litres of diesel** not burned and **98 fewer return truck trips**. See Figure 1 for an illustration of net project impacts in terms of diesel fuel savings, reduced number of truck trips and emissions reductions.

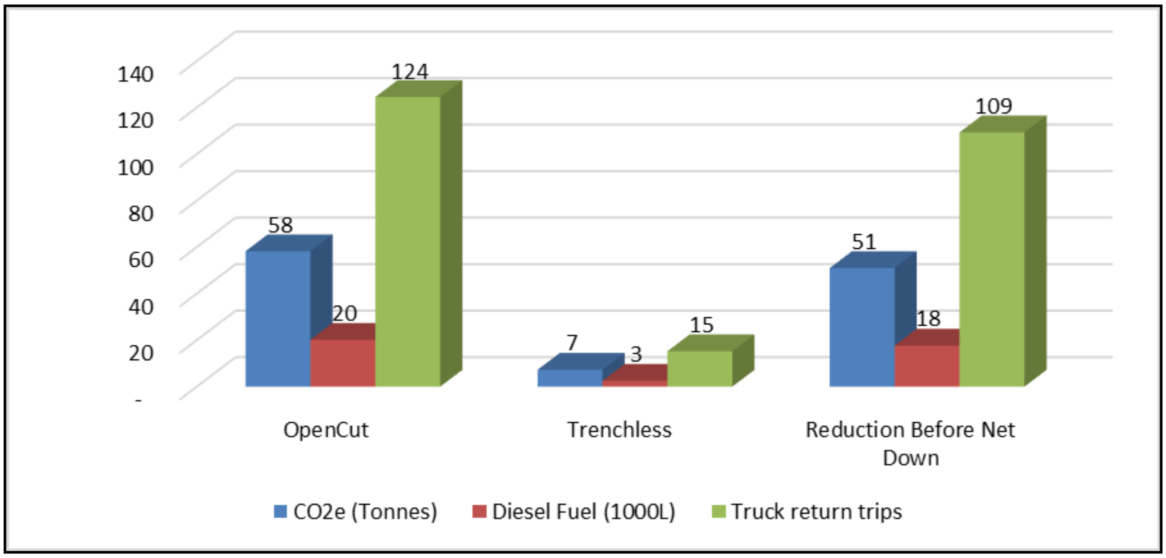

Figure 1. Emissions reductions, diesel fuel savings and reduction in the number of trips for the example trenchless project compared to a conventional open-cut trenching project.

Spreadsheet Directions

Step 1: Gathering essential data and supporting documents	
The following data from the trenchless project is essential to run the tool: **INPUTS TAB:** ○ Project name/number/address box 101 and the trenchless technology used box 102 ○ Pipe Diameter(mm) box 106, Pipe Length(m) box 107 ○ Soil Type (Light, Medium, Heavy, Hard Pan, Rock) box 103 and Soil Condition (Wet or Dry) box 104 ○ Number of near-side and far-side service/lateral connections and their length (m)	Most of the values required can be obtained in one or more of the following methods: **Extracted from project record drawings:** record drawings are relatively easy to obtain from engineering departments and most of the required data for the tool is readily available on the project summary section of each drawing. The length of the service connections is usually not included in the summary. These can be easily measured on the drawing by taking its scale into account. For example, a 1.18 cm connection on a 1:1000 scale drawing represents an 11.8m length connection. A very simple way to measure the length on the map is to use the free Foxit® reader. The “distance’

	tool in the top middle of the "comment" tab shows the section to set the scale of the drawing after being selected. Then clicking on the start of the connection and dragging to the end of it and clicking again will demonstrate to length of the connection. Soil type and condition needs to be obtained directly from city engineers or the contractor as it will not be found on the drawings. **Obtain from contractors:** Contractors can easily summarize and provide the required project data if informed in advance**.** Ideally, they should be informed of the data requested from them at the time of bidding or when awarding the contract. **Obtain data summary from engineering department:** Some record drawings do not include a summary section. Extracting project data from such drawings requires technical drawing reading skills and can be a time-consuming effort for non-engineers. In such cases it is best to request the summaries from the engineering departments until a process is put in place to collect and summarize the data at the time of the project by the contractor.
Step 2: Optional data fields	
Optional values: **INPUTS TAB:** o Surface Type box 105 o Pipe depth of installation at start and end of project(m) box 108 and box 109 o Percentage of excavated soil reused box 110 o Dump Truck Capacity box 111 o Distance from project site to dump site and/or gravel pit box 112 o Number of manholes including new ones box 113 o Number of entry and exit pits box 116 and box 117 o Number of runs/bursts Box 118 o Pit dimensions for manholes, service connections, and entry and exit pits Boxes 122 to 134 o Open cut trench upper and lower width Box 119 and Box 120 o Productivity for open cut Box 121 **MACHINERY TAB** o Machinery used for excavation and trenchless pipe replacement/restoration and their horsepower **PRODUCTIVITY TAB** o Productivity of trenchless technologies in meters/hour (or hours per run for Cured In Place Pipe and Pipe Bursting) Boxes 135 to 146 on productivity Tab	This is data for cells that the tool has or calculates alternative default values. Inputting values for these cells increases the accuracy of the calculations. Over time, local governments can establish procedures to have such data collected and summarized by contractors during the project.
Step 3: Data input	
o *Project Name/Number/Address* (Box 101) should match the project information on the supporting documents/record drawings o *Trenchless Technology* used (Box 102), *Soil Type* (Box 103), *Soil Condition* (Box 104), and surface type (Box 105) should be selected from the drop down menu for each line item o Input *Pipe Diameter* (Box 106) in millimetres and *Pipe Total Length* (Box 107) in meters in the yellow (user input) cells for the respective line item.	The yellow cells are for user input. Adjacent light blue cells show the default value used by the cell if no value is entered (independent default value) and the adjacent green cells show the default value as calculated from other cells (dependant default value) if no value is entered.

These two are mandatory inputs and an error will occur if no value is entred. o If available, input pipe (trench) *Depth* at start (Box 108) and end (Box 109) in meters o If available input the *Percentage of Excavated Soil Reused* (Box 110). As a general guideline, in urban areas it is common that all of excavated soil has to be replaced by virgin material (0% reused). In remote rural areas typically all excavated material can be reused (100% reused). The tool will assume 0% reuse as a default if no value is entered o Enter the *Dump Truck Capacity* (Box 111) if it has been obtained from the contractor. If no value is entered the tool will assumes the default value of 7.5m^3 from the reference cited o If available input the *Distance from project site to dump site and/or gravel pit* in kilometers (Box 112). If both distances are available enter the mean value o The *Number of Manholes* (Box 113) including new ones and number of *Near-Side* (Box 114) and *Far-side* (Box 115) *Lateral/Service Connections* should be entered in the respective yellow cells. The tool will assume a manhole for every 100m of pipe length if no value is entered. Number of connections is a mandatory number, no default value is assigned to the number of connections hence a "0" value is required for each if no connections exist o Enter the number of *Entry Pits* (Box 116) and *Exit Pits* (Box 117) o If available input values for the excavated *Pit dimensions for manholes, service connections, and entry and exit pits* in meters in boxes 122 to 134 o If the contractor has provided the *Number of Runs* or in the case of pipe bursting, "bursts", enter the value in Box 118 otherwise leave empty o If available, input values for the *Trench Upper Width* (Box 119) and *Trench Lower Width* (Box 120) otherwise the tool will use default values based on the Master Municipal Construction Documents. o If the trenchless project has an Open Cut component and the contractor has provided the Open Cut productivity value in meters progress per 8 hour day it can be entered in Box 121. The calculator will use this number for all the Open cut calculations instead of the default values o Boxes 135 to 146 in the "Productivity" tab allow for the user to input the Productivity of the trenchless project in meters/day (or hours per run for Cured In Place Pipe and Pipe Bursting) and override the default values from the listed references. No input is required on this tab if trenchless productivity data has not been collected o The user can add and edit the trenchless machinery and their horsepower in the yellow cells in the "Machinery" tab based on information provided by the contractor. No input is required on this tab if machinery data has not been collected	
Step 4: Results and Documentation	
o The "Output" tab demonstrates the steps of the calculations for both the open cut scenario and the trenchless project in a transparent and user-friendly manner o The summary results are provided both on the "Outputs" and the "Inputs" tab and include the following: o GHG savings (increase for negative values) in tonnes of CO2-equivalent o Trenchless GHG savings (increase for negative values) in Percentage of Trenchless to Open-Cut emissions o Litres of Diesel Fuel saved by using trenchless instead of Open Cut o No. of trucks off the road as a result of choosing trenchless technology o Number of fewer return trips by trucks as a result of choosing trenchless technology o Documentation supporting the input values used (record drawings. Engineer's/contractor's report, emails, etc.) should be filed with the calculation results for verification and submission to the GCC	Negative values for the outputs show that there has been an increase in emissions as a result of the trenchless technology and the open cut scenario would have resulted in less emissions/liters of diesel used, and number of trucks off the road

Carbon Neutral Framework and Trenchless Technology Compliance

The checklist below summarizes the seven Project Eligibility Requirements under the GCC Carbon Neutral Framework that a trenchless technology project must meet in order to be eligible for GHG reduction credits to reduce corporate emissions (for additional details see *Becoming Carbon Neutral: A Guidebook for Local Governments in British Columbia, Appendix 1, GCC Project Eligibility Requirements*).

1. Emission reductions are outside the local government's corporate emissions boundary:
    - Require that a Registered Professional Planner or Accountant attest in writing that the project is within the jurisdictional boundary of the local government, but outside of the local government's corporate emissions boundary as defined in *The Workbook*. In turn, the project is a capital project, and not part of general maintenance. ***Please refer to the note on additional eligibility requirements below.***
2. *Emission reductions have occurred before they are counted.*
    - The amount of emission reductions being claimed in a given year must have occurred by the end of that year
3. *Emission reductions are credibly measured:*
    - The local government is required to use the Trenchless Technology GHG Reduction Calculator prepared as part of this project profile.
4. *Emission reductions projects are beyond business as usual:*
    - For the credits from a project to be considered, open cut trenching has to be a viable option to the trenchless method. Reasons for open-cut not being possible could be lack of right of way rights, structures or obstacles blocking the way, or unfavourable ground conditions. In turn, require that a Registered Professional Planner or Accountant attest in writing that the project could have been done as an open trench project and no legal, physical or financial barrier would have made the use of open trenching impossible.
5. *Accounting of emission reductions is transparent.*
    - As part of the Option 1 Project Plan Template, a local government official must attest that they have read and understood the eligibility requirements.
6. *Emission reductions are counted only once.*
    - As part of the Option 1 Project Plan Template, a local government official must attest that they have read and understood the eligibility requirements.
7. *Project proponents have clear ownership of all emission reductions:*
    - Refer to ISO 14064-1 guidelines and only include projects that are either on municipally/RD owned or controlled land or that the local government has otherwise secured ownership of the generated credits.

In addition to meeting these seven eligibility requirements, local governments implementing a Trenchless Technology project must meet additional 'Trenchless Technology specific' eligibility requirements as outlined below.

✓ **Demonstrate that the project is a capital project and not general maintenance**
Activities related to maintenance of traditional services are included as "in scope" for purposes of corporate reporting under the GCC Carbon Neutral Framework. Maintenance is part of the annual expenses associated with the service or assets and necessary to maintain the integrity of the service or asset. Work paid for from general maintenance will not be eligible under this project profile.

Only work that is outside of the local government's corporate carbon inventory as per the GCC Carbon Neutral Framework (ie: capital projects) is eligible under the project profile. Capital or construction work is an infrequent, usually costly, activity that provides benefit for several years. Public Sector Accounting Board (PSAB) 3150 refers to Tangible Capital Assets (TCAs) and the construction or betterment of these TCAs are often capitalized over a longer period of time. Please refer to page 17 of *The Workbook* for more information.

Process and Precedents

A number of local governments are already using trenchless technologies in B.C. In January 2015, a pilot project was initiated with the City of New Westminster in which the municipality provided several years of records of their trenchless projects to use as case studies. Using the excel based calculator, the GHG emissions reductions from the City's 2010-2014 Trenchless projects were calculated to provide support for the third part validation and verification of credits. The results of the calculations showed that the use of trenchless pipe bursting and cured in place lined technologies instead of open-cut methods resulted in a reduction of 358.4 tonnes of CO2e, 124,000 less litres of diesel burnt, and an estimated 3280 fewer truck trips on city roads.

In February 2015 a process was initiated, in collaboration with a local trenchless technology company in which the calculator underwent testing and comparison against trenchless projects in progress. The site project manager from the trenchless company tracked all fuel use for the machinery on several projects (both trenchless and open cut), and the results were compared against the calculator inputs/outputs. This process made the default assumptions about certain input parameters more robust.

A local construction site inspector of trenchless projects was asked to review the tool to confirm the accuracy of certain assumptions. He conducts site inspections on behalf of different municipalities for many trenchless/open cut projects in the region, and conducted an informal "peer review" of the tool.

There are also precedents for calculating GHG reductions for trenchless projects. These precedents have informed this project profile and have been a valuable reference in ensuring that the present calculator produces a conservative estimate of emission reductions. The following calculators were identified and reviewed:

- NASTTBC/SFU Utility Carbon calculator
- The City of Los Angeles study on the GHG/Carbon Footprint reduction due to City of LA Public Works Construction Projects using trenchless
- UK Pipe Jacking Association calculator
- Arizona State University/ Vermeer E-Calc tool

Resources and References

The following are resources that were reviewed and/or cited in the course of the development of the Trenchless tool and profile document.

Adel, M., & Zayed, T. (2009). Productivity analysis of horizontal directional drilling. Pipelines 2009: Infrastructure's hidden assets (pp. 835-843)

Ahn, C., Lee, S., & Peña-Mora, F. (2011). Carbon emissions quantification and verification strategies for large-scale construction projects. ICSDC 2011: Integrating Sustainability Practices in the Construction Industry, pp. 1-8.

Ahn, C., Pan, W., Lee, S., & Peña-Mora, F. (2010). Enhanced estimation of air emissions from construction operations based on discrete-event simulation. Computing in Civil and Building Engineering, Proceedings of the International Conference, (ICCCBE), Nottingham, U.K. (119) pp. 237.

Allouche, E. N., Ariaratnam, S. T., & Lueke, J. S. (2000). Horizontal directional drilling: Profile of an emerging industry. Journal of Construction Engineering and Management, 126(1), 68-76.

Ariaratnam, S.,T.,(2011). Sustainable development through innovative underground infrastructure construction practices. ICSECM 2011 - International Conference on Structural Engineering, Construction and Management (15th to 17th December 2011), Kandy - Sri Lanka.

Ariaratnam, S.,T., and Sihabuddin, S., (2009). Comparison of emitted emissions between trenchless pipe replacement and open cut utility construction. Journal of Green Buildings, Volume 4, Number 2. Available at: http://www.journalofgreenbuilding.com/doi/abs/10.3992/jgb.4.2.126

Bauer, C., Dubetz, C., Freeman, D., Grainger, M., & Millen, T. (1998). An environmental review of hot in-place recycling in british columbia Royal Roads University.

Beale, D. J., Marlow, D. R., & Cook, S. (2013). Estimating the cost and carbon impact of a long term water main rehabilitation strategy. Water Resources Management, 1-12.

Bizier, P. (2007). Gravity sanitary sewer design and construction Water Environment Foundation (WEF).

Calderon, D., & Najafi, M. (2009). New approaches to trenchless renewal of culverts. Pipelines 2009: Infrastructure's hidden assets (pp. 865-875)

CES, R. The greenhouse gas protocol.

Chaurasia, B. B. (2013). Identifying issues impacting productivity of box jacking projects.

Du, F., Woods, G., Kang, D., Lansey, K., & Arnold, R. (2013). Life cycle analysis for water and wastewater pipe materials. Journal of Environmental Engineering, 139(5), 703-711.

Energy, E. (2011). 3 The inventory of carbon and energy. Embodied Carbon,

Hanks, K., Uong, E., Shammas, L., & Cheng, S.,. (2013). Trenchless in los angles, secondary sewer rehabilitation carbon footprint. North American Society for Trenchless Tehnology (NASTT) no-Dig Conference, Sacramento, California. (TM1-T1-01)

Hashemi, B., Iseley, T., & Raulston, J. (2011). Water pipeline renewal evaluation using AWWA class IVCIPP, pipe bursting, and open-cut.

Horvath, A.,. (2005). Life-cycle energy assessment of alternative water supply systems in california. No. CEC-500-2005-101). Berkeley: University of California, Berkeley.

Hunt, D. V. L., Nash, D., & Rogers, C. D. F. Sustainable utility placement via multi-utility tunnels. Tunnelling and Underground Space Technology.

Iseley, T. (1997). Trenchless installation of conduits beneath roadways Transportation Research Board.

Jung, Y. J., & Sinha, S. K. (2007). Evaluation of trenchless technology methods for municipal infrastructure system. Journal of Infrastructure Systems, 13(2), 144-156.

Kean, A. J., Sawyer, R. F., & Harley, R. A. (2000). A fuel-based assessment of off-road diesel engine emissions. Journal of the Air & Waste Management Association, 50(11), 1929-1939.

Knight, M., Younis, R., Zhou, H., and Nowak, T., 2014. “2013 Municipal Buried Infrastructure Survey: An overview of Canada’s water, wastewater and storm water sectors”. Centre for Advancement of Trenchless Technologies, University of Waterloo, May 2014. Available at: http://cattevents.ca/pdf/2013_CATT_Municipal_Survey.pdf

Lewis, M. P.,. (2009). Estimating fuel use and emission rates of nonroad diesel construction equipment performing representative duty cycles. (PhD, North Carolina State University).

Loiacono, J., & Cote, B.,. (2013). 350+ towns and cities can't be wrong! considerable water, money and GHG savings with CIPP water rehabilitation. North American Society for Trenchless Technology (NASTT) no-Dig Conference, Sacramento, California. (TM2-T3-03)

Matthews, J. C., Ariaratnam, S. T., SELVAKUMAR, A., & Condit, W. (2012, March 11-15). Evaluation of the carbon footprint of innovative water main rehabilitation technologies vs. open cut methods. No-Dig 2012, Nashville, TN. , Paper F-4-02.

Matthews, J., & Gutierrez Monsalve, J. (2012). Trenchless infrastructure construction techniques used in colombia. Practice Periodical on Structural Design and Construction, 17(4), 166-170.

Najafi, M. (2013). Trenchless technology: Planning, equipment, and methods McGraw-Hill New York.

Najafi, M., & Gokhale, S. (2005). Trenchless technology: Pipeline and utility design, construction, and renewal McGraw-Hill NY.

O'Sullivan, D., (2014) Interview with David O'Sullivan, Trenchless contractor in BC since 1990, On 25 June, 2014 at 16:00

Pallant, J., 2011. “GHG Protocol: Trenchless Construction Protocol: Fuel Efficiency and Reduced Asphalt Production”. Draft Protocol prepared by Habitat Carbon Assets. Available at: http://www.pwtrenchless.com/Trenchless_Protocol1_0.pdf

Page, J. S. (1999). Estimator's piping man-hour manual Elsevier.

Piratla, K.,R., Ariaratnam, S.,T., & Cohen, A.,. (2012). Estimation of CO2 emissions from the life cycle of a potable water pipeline project. Journal of Management in Engineering, (28), 22.

Pyzoha, D., S.,. (July 2013). An economical and sustainable alternative to open-cut construction for small-diameter water main rehabilitation. Journal - American Water Works Association, 105(7), 64-77.

Rehan, R., and Knight, M., 2007. “Do Trenchless Pipeline Construction Methods Reduce Greenhouse Gas Emissions?”. Centre for Advancement of Trenchless Technologies, University of Waterloo. Available at: http://www.pwtrenchless.com/assets/preliminaryco2report-sept-07.pdf

Salem, O., Galani, N., & Najafi, M. (2003). Productivity analysis of auger boring trenchless pipe installation using simulation. New pipeline technologies, security, and safety (pp. 953-963)

Sihabuddin, S., & Ariaratnam, S.,T.,. (2009). Quantification of carbon footprint on underground utility projects. Seattle, Washington. pp. 618.

Sihabuddin, S., & Ariaratnam, S. (2009). Methodology for estimating emissions in underground utility construction operations. Journal of Engineering, Design and Technology, 7(1), 37-64.

Zayed, T., Amer, M. I., & Gupta, M. (2007). Deterministic productivity model for horizontal directional drilling. Twelfth International Colloquium on Structural and Geotechnical Engineering,

Zhang, B., Ariaratnam, S.,T., & Wu, J.,. (October 19-22, 2012). Estimation of Co2 emissions in A wastewater pipeline project. International Conference on Pipelines and Trenchless Technology. Wuhan, China.