



No. 27

**Carbon calculator for CIPP relining
Version 2.2**

**(Manual for using of the
calculation programm)**

May 2014

why cracking trenches, if there are better solutions!

Users notice

In this GSTT-Information, the current state of affairs is represented by the topics covered in the table of content at the time of first publication. This information is free to all persons, to any, even for training and courses. An obligation to use does not exist.

Who it applies, has to take care for the correct application in specific cases. By using this information, no one escapes of responsibility for his own actions.

Despite careful control and careful processing by professionals a guarantee for the correctness can't be accepted.

Legal notice / copyright

All rights, especially the translation, are reserved to the GSTT.

Any commercial use, as well as the reproduction and photomechanical report, even in part, is only permitted with the approval of the GSTT.

It is always to specify a source of evidence to the GSTT.

Except of it only in use in the preparation of bills of quantities or as a quotation with regard to the reference.

Disclaimer

The publishers does not accept any liability whatsoever for possible typographical, technical or other inaccuracies, for errors and omissions or their consequences.

The publishers reserve the right to change the document from time to time. If this document refers to products of third party suppliers, the publisher does not accept any liability for such products.

Notes on use

This user manual describes the "Energy Calculator" for calculation of CO2 emissions during use of the pipe lining method.

As use of pipe lining is widespread, this tool is in English, and is therefore designed for international use.

Calculation with the "Energy Calculator" requires, among other things, precise knowledge of the process parameters. In case of difficulties with the input, please refer to the FAQs/Troubleshooting section for help.

If you have any further questions or ideas, you can contact us at one of the following email-adresses:

info@gstt.de

info@bkp-berolina.de

multicom@saertex.com

Preamble

Dear Readers
of the GSTT-Informationen no. 27,

since the beginning of industrialization, carbon emissions have risen significantly. The anthropogenic carbon emissions from the combustion of fossil fuels accounts for the most significant share of emissions and is developing into a global environmental problem. There-fore, the emissions by greenhouse gases must be reduced in all areas, of course, not only in the industry or road traffic, but also in civil engineering.



In the field of civil engineering, the magnitude of the carbon emissions are very dependent on the type of technology used. Trenchless technologies and especially the avoidance or reduction of construction-related detours and traffic jams caused by the construction activities, can reduce carbon emissions dramatically.

It's possible to create a so-called "product carbon footprint" for every product and every service. In recent years this carbon footprint becomes more and more important and in many areas a uniform "carbon labeling of goods and services" is discussed. In the building industry, there are already approaches to take the carbon footprint in the future into account as an award criterion.

Our Association has been arguing with this subject extensively for some years. Another component of this is the Energy Calculator.

With the "Energy Calculator", a calculation template is provided, which allows to determine the system-induced carbon emissions resulting from 3 different pipe relining methods and to compare them. By entering project-specific boundary conditions, the user is given the opportunity to predict the installation emissions for specific projects.

I especially would like to thank my two former Bachelor students Mr. Tom Küter and Mr. Christoph Klempert who essentially created the "Energy Calculator" as part of their thesis.

We've tried to create the "Energy Calculator" as transparent as possible and we would be very pleased and would be grateful for suggestions for improvement.

A handwritten signature in blue ink, appearing to read 'Jens Fröhne'. The signature is written in a cursive, flowing style.

Berlin, May 2014

Carbon calculator for CIPP relining - Version 2.2

May 2014

CONTENTS

| | page |
|--|------|
| Introduction | 5 |
| User interface | 6 |
| Tutorial (Making entries in the calculation template) | 9 |
| General information | 9 |
| 1. General project data (Project details) | 9 |
| 2. Process-specific inputs | 12 |
| 2.1. Synthetic non-woven (non-woven liner details) | 12 |
| 3.2.1 a) Synthetic non-woven with water curing (water curing data) | 13 |
| 3.2.1 b) Synthetic non-woven with steam curing (steam curing data) | 14 |
| 3.2.2 GRP liner with UV curing (UV light curing data) | 16 |
| 3.3 Other entries | 17 |
| 3.4 Results | 18 |
| 4 Other functions | 20 |
| 4.1 Overview (calculation all diameters) | 20 |
| 4.2 Diagrams | 22 |
| 4.2.1 "Diagrams" | 22 |
| 4.2.2 "Emission on site/ manufacturing/ total -kg, -oz, -%" | 24 |
| 5 FAQs / Troubleshooting | 29 |
| Authors | 31 |

1. Introduction

This user manual describes the "Energy Calculator", a calculation template, which allows to determine the system-induced carbon emissions resulting from 3 different pipe relining methods and to compare them. By entering project-specific boundary conditions, the user is given the opportunity to predict the installation emissions for specific projects. Furthermore, it is determined for each method, the carbon emissions in the production of the liner in the factory and during transport to site. It should be noted that in this case the CO₂ equivalent is determined. Based on market shares, hot water and steam curing only are taken into account for synthetic non-woven liners and UV curing for GRP liners. The manual focuses on the easy calculation of installation emissions, individually for each method and by way of an example calculation (tutorial).

Furthermore, it discusses the results of other special inputs and other functions of the program.

The program is made up of different worksheets. The first is an input mask relevant for the user. Furthermore, the calculation tables for each individual method are located on separate worksheets. In addition, the "Energy Calculator" contains an overview and diagrams for showing calculation results.

The "Energy Calculator" is based on a comprehensive Microsoft Excel calculation and is implemented with the help of this platform. Therefore, there is no need to install any other programs or for the user to familiarize themselves with new software. The very low system requirements are therefore based on the specification for the Microsoft Excel data processing (spreadsheet) program.

Through exemplary and liberally illustrated explanations, the user manual provides a useful and convenient introduction to use and servicing of the program. The systematic layout is like a central thread, guiding you through the tasks and the interaction of the individual controls.

This manual also serves as a reference, providing answers to specific questions.

2. User interface

The user interface of the input mask (screen form) is presented in the form of a Microsoft Excel spreadsheet and consists of a worksheet. The entire calculation, apart from the input fields provided, is protected against editing, so that all other Excel functions are of no significance to the user.

The input mask is made up of the "Input Data" and "Results" areas (see Figure 1a, Figure 1b und Figure 2). In the "Input Data" area the table is divided into individual sections, separated from each other by a black bar. These sections consist of the general project data and the process-specific input data for each method.

The individual sections are structured as follows: The left-hand part represents the parameter description of the respective input fields (columns A-D). Next to these is the input field (columns E/F). As the program is designed for international use, all inputs can be made using the US American system of units (column E) and the metric system (column F). The calculation value is output to the right of the input field (column G). This column is also used for checking and outputs the error value "False" or "#Wert!" if the input is wrong.

The results of the calculation are shown at the end of the worksheet, in the "Results" area. Here too, the individual results are shown for both systems of measurement and units.

The individual sections and methods are represented by different colors for improved clarity and to differentiate between them. This ensures fast familiarization with the program and enables information to be read out quickly.

GSTT-Information no. 27 – Carbon Calculator - Version 2.2

- 7 -

| | A | B | C | D | E | F | G | |
|----|---|---|---|---|-------------------------------|-------------------|--------------|----------------------------|
| 1 | | | | | | Input Data | | resulting calculation data |
| 2 | Project details: | | | | | | | |
| | | | | | imperial (customary units) | metric | | |
| 3 | ID _{host pipe} = OD _{Liner} (please enter "in" or "mm" only): | | | | | 1000 mm | 1,000 m | |
| 4 | Choose host pipe ("1" for concrete; "2" for vitrified clay; "3" for PVC; "4" for sewer brick): | | | | 1 | | concrete | |
| 5 | | | | | | | | |
| 6 | Wall thickness of host pipe (please enter "in" or "mm"): | | | | | 50,0 mm | 50,0 mm | |
| 7 | optional: Volume bypass water (enter "gal/h" or "m³/h): | | | | | | 0,0 m³/h | |
| 8 | optional: Bypass pump used (please enter "kW"): | | | | | | 0,0 kW | |
| 9 | transport by truck ^[1] (enter "mi" and/or "km") | | | | | 500,0 km | 500,0 km | |
| 10 | transport by train (enter "mi" and/or "km") | | | | | | 0,0 km | |
| 11 | transport by container ship (enter "nautical miles" or "km") | | | | | | 0,0 km | |
| 12 | Length of section (enter "ft" or "m"): | | | | | 1000,0 m | 1000,00 m | |
| 13 | | | | | | | | |
| 14 | | | | | | | | |
| 15 | | | | | | | | |
| 16 | Felt liner details: | | | | | | | |
| | | | | | imperial | metric | | |
| 17 | Wall thickness of felt liner (please see value in Table "Diagram") (enter "in" or "mm"): | | | | | 5,0 mm | 0,005 m | |
| 18 | ID _{Liner Felt} | | | | | | 0,990 m | |
| 19 | Delivery temperature of liner (please enter degF or degC): | | | | | 5 °C | 5 °C | |
| 20 | Ground temperature (host pipe) (we suggest to leave ground temperature at 18°C ≈ 65°F if no measures were taken): | | | | | 18 °C | 18 °C | |
| 21 | Temperature of process water at the beginning (please enter degF or degC): | | | | | 20 °C | 20 °C | |
| 22 | Choose coating ("1" for PE; "2" for PP; "3" for PU): | | | | 1 | | PE | |
| 23 | Fitting with Preliner (enter "yes" or "no") | | | | yes | | yes | |
| 24 | Water curing data: | | | | | | | |
| | | | | | imperial | metric | | |
| 25 | Holding temperature during curing (please enter degF or degC): | | | | | 90 °C | 90 °C | |
| 26 | Minimum temperature at liner outside (please enter degF or degC): | | | | | 60 °C | 60 °C | |
| 27 | Curing time - holding time of temperature (please enter hours and/or minutes): | | | | 1,00 h | 45 min | 1,75000000 h | |
| 28 | optional: Volume flow of water in liner (enter "gal/h" or "m³/h): | | | | | | ----- | |
| 29 | Capacity of circulation pumps used (please enter "kW"): | | | | 12,0 kW | | 12,0 kW | |
| 30 | optional: Heat capacity of equipment used (please enter "kW"): | | | | | | ----- | |
| 31 | Steam curing data: | | | | | | | |
| | | | | | imperial | metric | | |
| 32 | Minimum Temperature at liner outside (please enter degF or degC): | | | | | 80 °C | 80 °C | |
| 33 | Minimum temperature during curing at outlet (please enter degF or degC) (T _{min} must be higher than minimum Temperature at liner outside): | | | | | 90 °C | 90 °C | |
| 34 | Maximum temperature during curing - input temperature (please enter degF or degC): | | | | | 150 °C | 150 °C | |
| 35 | Surrounding air temperature at site (please enter degF or degC): | | | | | 20 °C | 20 °C | |
| 36 | Curing time - holding time of temperature (please enter hours and/or minutes): | | | | 1,00 h | 45 min | 1,75000000 h | |
| 37 | Flowrate of steam in liner (enter in/sec or m/sec only): | | | | 20 in/sec | | 0,51 m/sec | |
| 38 | Mass proportion of steam concentration in hot air (enter %): | | | | 20% | | 0,20 | |
| 39 | optional: Heat capacity of equipment used (please enter "kW"): | | | | | | ----- | |

Figure 1a (Input data – part 1)

| | | Input Data | | resulting calculation data |
|----|--|-------------|---------|----------------------------|
| 1 | | | | |
| 43 | UV- light curing data: | imperial | metric | |
| 44 | Wall thickness of UV-liner (please see value in Table"Diagram") | | 5,0 mm | 5,0 mm |
| 45 | ID _{Liner UV} | | | 0,990 m |
| 46 | Generator used (Max capacity needed for starting lamps), (please enter "KVA"): | 24,0 KVA | | 24,0 KVA |
| 47 | Average output over total time (please enter "%"): | 60,0% | | 60,0% |
| 48 | Choose coating ("1" for PE; "2" for PVC): | 1 | | PE |
| 49 | | | | |
| 50 | | | | |
| 51 | | | | |
| 52 | Market Prices (optional): | | | |
| 53 | USA only: costs of diesel (enter USD per gallon): | 3,90 | \$/gal | |
| 54 | Europe only: costs diesel (enter EUR per liter): | 1,40 | EUR/ltr | |
| 55 | USA only: costs of fuel oil (enter USD per gallon): | 3,90 | \$/gal | |
| 56 | Europe only: costs of fuel oil (enter EUR per liter): | 0,83 | EUR/ltr | |
| 57 | | | | |
| 58 | Efficiency of current generators: | 0,95 - 0,99 | 0,95 | |
| 59 | Efficiency of heating burners: | ≈ 0,9 : | 0,9 | |
| 60 | | | | |
| 61 | specific consumption of Diesel generators (240-270 g/kWh): | 240 | g/kWh | |

Figure 1b (Input data - part 2)

| Results: | | | | | | | | | |
|-----------------|--|------------------------------------|---|------------------------------------|--|-------------------------|------------------------------------|------------------------------------|--------------|
| 63 | Energy capacity of fuel oil (Diesel) per liter: | | | | 10,68 kWh/ltr | | | | |
| 64 | specific consumption of Diesel generators: | | | | 240 g/kWh | | | | |
| 65 | specific weight of fuel oil (Diesel): | | | | 0,87 kg/ltr | | | | |
| 66 | 1 ltr = | | | | 0,2642 gallon | | | | |
| 67 | Carbon (CO ₂) equivalent when burning fuel oil (Diesel): | | | | 2,65 kg/ltr | | | | |
| 68 | | | | | | | | | |
| 69 | | | | | | | | | |
| 70 | total heat quantity per section | | fuel oil + diesel per section | | costs per (only for fitting) | | | | |
| 71 | | | | | Europe | | USA | | |
| 72 | [kWh] | | [liters] | [gallons] | [€ per section] | [€/m] | [\$/ft] | [\$ per section] | |
| 73 | Water curing: | 75.108,60 kWh | 7.823,44 ltr | 2.066,95 gal | 6.501,79 € | 6,50 €/m | \$2,46/ft | \$8.061,11 | |
| 74 | Steam curing: | 13.313,13 kWh | 1.385,05 ltr | 365,93 gal | 1.149,59 € | 1,15 €/m | \$0,43/ft | \$1.427,13 | |
| 75 | UV-light curing: | 744,39 kWh | 216,16 ltr | 57,11 gal | 302,62 € | 0,30 €/m | \$0,07/ft | \$222,72 | |
| 76 | carbon emission per section (only manufacturing) | | carbon emission per section (only transportation) | | carbon emission per section (only fitting) | | total: carbon emission per section | | |
| 77 | Europe | | USA | | Europe | | USA | | |
| 78 | [kg CO ₂ equivalent] | [lbs CO ₂ equivalent] | [kg CO ₂ equivalent] | [lbs CO ₂ equivalent] | [kg CO ₂] | [lbs CO ₂] | [kg CO ₂ equivalent] | [lbs CO ₂ equivalent] | |
| 79 | Water curing: | 74980,1 kg | 165302,9 lbs | 625,5 kg | 1379,0 lbs | 20.732,1 kg | 45.706,5 lbs | 96337,7 kg | 212388,3 lbs |
| 80 | Steam curing: | 74980,1 kg | 165302,9 lbs | 625,5 kg | 1379,0 lbs | 3.670,4 kg | 8.091,8 lbs | 79276,0 kg | 174773,7 lbs |
| 81 | UV-light curing: | 104314,6 kg | 229974,4 lbs | 753,1 kg | 1660,2 lbs | 572,8 kg | 1.262,8 lbs | 105640,5 kg | 232897,4 lbs |

Figure 2 (Results)

3. Tutorial (Making entries in the calculation template)

General information

The purpose of this tutorial is to guide you, step-by-step, through the spreadsheet, assisted by graphic illustrations and an example calculation, and to facilitate use of the program.

After you have started the "Energy Calculator" in Microsoft Excel, the input mask appears immediately. First, you enter the general project data in the "Input Data" area of the input mask. The basic procedure for entering data and its special features are also described here. Then, individual, specific entries must be made for each method. The results of the calculation can then be read at the end of the worksheet, in the "Results" area.

Before you begin to use the application, we would like to point out that you should familiarize yourself with the user interface first, to prevent questions and possible problems in understanding the instructions.

3.1. Allgemeine Projektdaten (Project details)

The general project data is entered in the first section. If no previous calculations have been saved the mask is empty.

This section is made up of the following entries (see Figure 3):

- Inner diameter (hose pipe) / outer diameter (liner)
- Choice of host pipe material ("1" Concrete; "2" Ceramic; "3" PVC; "4" Masonry)
- Wall thickness of the host pipe
- Flow rate **(optional)**
- Capacity of the flow pump **(optional)**

- Transport routes
- Section length

| | A | B | C | D | E | F | G |
|----|---|---|---|---|-------------------------------|--------------------------|----------------------------|
| 1 | | | | | Input Data | | resulting calculation data |
| 2 | Project details: | | | | imperial (customary units) | metric | |
| 3 | ID _{host pipe} = OD _{Liner} (please enter "in" or "mm" only): | | | | | <input type="checkbox"/> | False |
| 4 | Choose host pipe ("1" for concrete; "2" for vitrified clay; "3" for PVC; "4" for sewer brick): | | | | | | False |
| 5 | | | | | | | |
| 6 | Wall thickness of host pipe (please enter "in" or "mm"): | | | | | | False |
| 7 | optional: Volume bypass water (enter "gal/h" or "m³/h): | | | | | | 0,00 m³/h |
| 8 | optional: Bypass pump used (please enter "kW"): | | | | | | 0,0 kW |
| 9 | transport by truck ^[1] (enter "mi" and/or "km") | | | | | | False |
| 10 | transport by train (enter "mi" and/or "km") | | | | | | 0,0 km |
| 11 | transport by container ship (enter "nautical miles" or "km") | | | | | | 0,0 km |
| 12 | Length of section (enter "ft" or "m"): | | | | | | False |

Figure 3 (Project details)

You can now start straight away to fill the input fields (column E/F) from the top down.

- *To do this, move the cursor above the required input field and click in it.*
- *Then enter your value for the respective parameter and confirm with "Enter" or by clicking another field.*

The relevant units are given in the parameter description (columns A-D). If the fields already contain values from previous calculations, you can simply overwrite them.

- *Please note that only one input field is to be filled for the respective parameter, i.e. you must decide to either use the US American system of units or the metric system, where this choice exists.*
- *Only when entering the transport routes for trucks and freight train it's possible to enter both kilometers and miles. Furthermore, the input of the transport route with the ship can be done in nautical miles or kilometres.*

| | A | B | C | D | E | F | G |
|----|---|---|---|---|-------------------------------|----------|----------------------------|
| 1 | | | | | Input Data | | resulting calculation data |
| 2 | Project details: | | | | imperial (customary units) | metric | |
| 3 | ID _{host pipe} = OD _{Liner} (please enter "in" or "mm" only): | | | | | 250 mm | 0,250 m |
| 4 | Choose host pipe ("1" for concrete; "2" for vitrified clay; "3" for PVC; "4" for sewer brick): | | | | 1 | | concrete |
| 5 | | | | | | | |
| 6 | Wall thickness of host pipe (please enter "in" or "mm"): | | | | 2,0 in | 50,0 mm | False |
| 7 | optional: Volume bypass water (enter "gal/h" or "m³/h): | | | | | | 0,00 m³/h |
| 8 | optional: Bypass pump used (please enter "kW"): | | | | 12,0 kW | | 12,0 kW |
| 9 | transport by truck ^[1] (enter "mi" and/or "km") | | | | | 500,0 km | 500,0 km |
| 10 | transport by train (enter "mi" and/or "km") | | | | | | 0,0 km |
| 11 | transport by container ship (enter "nautical miles" or "km") | | | | 3000,0 nmi | | 5556,0 km |
| 12 | Length of section (enter "ft" or "m"): | | | | | 100,0 m | 100,00 m |

Figure 4 (Project details, filled)

After entering a value, the corresponding calculation value appears on the right, next to the input field (column G). However, if "False" is output in this field, you must check your entry and then correct it, see Figure 4 row 6. The cause of the error in this case is that both input fields have been filled.

- *Furthermore, this calculation includes inputs, which are limited by specific requirements in the parameter description (see row 4 and 5).*
- *This calculation also contains optional input fields, in these cases, before you enter a value, a zero value (see row 7) or the symbol "-----" is shown as the calculation value.*

In this section, details of the flow rate (row 7) and the flow pump (row 8) are not absolutely necessary for the calculation. The flow rate is merely for informative purposes and is not incorporated in the calculation. *The capacity of the flow pump, on the other hand, should be entered if used, as it affects the CO₂ emissions on the construction site.*

Entry of the general project data is now completed and you can continue by entering the process-specific parameters.

3.2. Process-specific inputs

In this step you must enter details of all installation methods, which are to be taken into account in the calculation.

To calculate the CO₂ emissions for construction projects with synthetic non-woven liners, continue in section 3.2.1.

For calculation of the CO₂ emissions during the production and the installation of GRP liners using UV curing, please jump to section 3.2.2. on page 16.

3.2.1. Synthetic non-woven (non-woven liner details)

This section deals with the data input for the installation method using synthetic non-woven liners. Use the same procedure as the one described in section 3.1.

First, please enter the general data for the method with synthetic non-woven liners in the "non-woven liner details" mask!

The following entries must be made (see Figure 5):

- Wall thickness of the synthetic non-woven liner
- Liner temperature on delivery
- Ground temperature
- Process water temperature at the beginning
- Choice of coating („1“ polyethylen; „2“ polypropylen; „3“ polyurethan)
- Using Preliner

Note: If the ground temperature in row 20 cannot be entered due to lack of information, we recommend performing the calculation using the value from the parameter description.

| 16 Felt liner details: | | imperial | metric |
|------------------------|---|----------|-------------------|
| 17 | Wall thickness of felt liner (please see value in Table "Diagram") (enter "in" or "mm") | | 5,0 mm 0,005 m |
| 18 | ID _{Liner Felt} | | 0,490 m |
| 19 | Delivery temperature of liner (please enter degF or degC): | | 5 °C 5 °C |
| 20 | Ground temperature (host pipe) (we suggest to leave ground temperature at 18°C ≈ 65°F if no measures were taken): | | 18 °C 18 °C |
| 21 | Temperature of process water at the beginning (please enter degF or degC): | | 20 °C 20 °C |
| 22 | Choose coating ("1" for PE; "2" for PP; "3" for PU): | 1 | PE |
| 23 | Fitting with Preliner (enter "yes" or "no") | yes | yes |

Figure 5 (non-woven liner details)

Then continue with the entries for hot water or steam curing.

For hot water curing, continue in section 3.2.1.a on page 13.

For steam curing, continue in section 3.2.1.b page 14.

3.2.1.a) Synthetic non-woven with water curing (Water curing data)

Here you must enter specific details of the hot water curing. The entries are made analogous to the preceding steps.

The following entries must be made (see Figure 6):

- Temperature during the hold phase
- Minimum temperature outside on the liner
- Duration of the hold phase
- Volumetric flow in the liner (**optional**)
- Circulation pump capacity
- Capacity of the heater (**optional**)

Note Rows 28 and 30:

- *The entry for the volumetric flow in row 28 is voluntary and does not have any effect on the calculation.*
- *The entry in row 30 enables you to perform the calculation with equipment output for the heater, which you have defined yourself.*

Note: The lack of an entry for the heater in row 30 means that the program calculates using an idealized minimum size for the heater, which it determines from the energy calculation. This can cause differences in the calculation of the resulting CO₂ emissions!

| 24 Water curing data: | | imperial | metric | |
|-----------------------|---|----------|--------|--------------|
| 25 | Holding temperature during curing (please enter degF or degC): | | 90 °C | 90 °C |
| 26 | Minimum temperature at liner outside (please enter degF or degC): | | 60 °C | 60 °C |
| 27 | Curing time - holding time of temperature (please enter hours and/or minutes): | 1,00 h | 45 min | 1,75000000 h |
| 28 | optional: Volume flow of water in liner (enter "gal/h" or "m ³ /h): | | | ----- |
| 29 | Capacity of circulation pumps used (please enter "kW"): | 12,0 kW | | 12,0 kW |
| 30 | optional: Heat capacity of equipment used (please enter "kW"): | | | ----- |

Figure 6 (Water curing data)

The entries for this method are now completed. Next, you must enter further information; please refer to section 3.3. on page 17.

3.2.1.b) Synthetic non-woven with steam curing (Steam curing data)

Here you must enter specific details of the steam curing. The entries are made analogous to the preceding steps.

The following entries must be made (see Figure 7):

- Minimum temperature outside on the liner
- Minimum temperature at the outlet during the hold phase
- Maximum temperature during the hold phase
- Ambient temperature on the construction site
- Duration of the hold phase
- Steam flow rate
- Steam content in hot air
- Capacity of the heater (**optional**)

Note Rows 33 and 39:

- *The entry for the minimum temperature in row 33 must be higher than the temperature on the outside of the liner (row 32), because otherwise the liner cannot be properly cured, especially at the outlet.*
- *The entry in row 39 enables you to perform the calculation with equipment output for the heater, which you have defined yourself.*

Note: The lack of an entry for the heater in row 39 means that the program calculates using an idealized minimum size for the heater, which it determines from the energy calculation. This can cause differences in the calculation of the resulting CO₂ emissions!

| 31 Steam curing data: | | imperial | metric | |
|------------------------------|--|-----------|--------|--------------|
| 32 | Minimum Temperature at liner outside (please enter degF or degC): | | 80 °C | 80 °C |
| 33 | Minimum temperature during curing at outlet (please enter degF or degC) (Tmin must be higher than minimum Temperature at liner outside): | | 90 °C | 90 °C |
| 34 | Maximum temperature during curing - input temperature (please enter degF or degC): | | 150 °C | 150 °C |
| 35 | Surrounding air temperature at site (please enter degF or degC): | | 20 °C | 20 °C |
| 36 | Curing time - holding time of temperature (please enter hours and/or minutes): | 1,00 h | 45 min | 1,75000000 h |
| 37 | Flowrate of steam in liner (enter in/sec or m/sec only): | 20 in/sec | | 0,51 m/sec |
| 38 | Mass proportion of steam concentration in hot air (enter %): | 20% | | 0,20 |
| 39 | optional: Heat capacity of equipment used (please enter "kW"): | | | ----- |

Figure 7 (Steam curing data)

The entries for this method are now completed. Next, you must enter further information; please refer to section 3.3. on page 17.

3.2.2. GRP liner with UV curing (UV light curing data)

This section deals with the data input for the installation method using UV cured GRP liners. Use the same procedure as the one described in section 3.1.

The following entries must be made (see Figure 8):

- Wall thickness of the GRP liner
- Generator capacity
- Average capacity utilization of the generator
- Choice of coating („1“ polyethylen; „2“ polyvinylchlorid)

| 43 | UV- light curing data: | imperial | metric |
|----|--|----------|----------|
| 44 | Wall thickness of UV-liner (please see value in Table"Diagram") | | 5,0 mm |
| 45 | ID _{Liner UV} | | 0,490 m |
| 46 | Generator used (Max capacity needed for starting lamps), (please enter "KVA"): | 24,0 KVA | 24,0 KVA |
| 47 | Average output over total time (please enter "%"): | 60,0% | 60,0% |
| 48 | Choose coating ("1" for PE; "2" for PVC): | 1 | PE |

Figure 8 (UV light curing data)

3.3. Other entries

The other entries represent the completion of the input and are to be edited with the same procedure as the one described in the previous steps. The entry fields are also color coded, only in this section they are arranged differently. In addition, column G for the calculation values only contains the error values in case of incorrect input.

The other entries are made up of details of market prices for fuels, efficiencies and the fuel consumption of the diesel generator.

The following entries must be made (see Figure 9):

- Diesel costs (dollar) (**optional**)
- Diesel costs (euro) (**optional**)
- Heating oil costs (dollar) (**optional**)
- Heating oil costs (euro) (**optional**)
- Efficiency of the electricity generator
- Efficiency of the heating burner
- Specific consumption of the diesel generator

Instead of "US dollar" or "euro", any other national currency can be used here.

Note: If there are no details of market prices in Rows 55-58, "False" is output in column G. A CO₂ calculation is still performed, however, please note that the "Results" area will therefore not be able to provide any cost information.

| | | | | |
|----|--|--|-------------|---------|
| 52 | Market Prices (optional): | | | |
| 53 | USA only: costs of diesel (enter USD per gallon): | | 3,90 | \$/gal |
| 54 | Europe only: costs diesel (enter EUR per liter): | | 1,40 | EUR/ltr |
| 55 | USA only: costs of fuel oil (enter USD per gallon): | | 3,90 | \$/gal |
| 56 | Europe only: costs of fuel oil (enter EUR per liter): | | 0,83 | EUR/ltr |
| 57 | | | | |
| 58 | Efficiency of current generators: | | 0,95 - 0,99 | 0,95 |
| 59 | Efficiency of heating burners: | | ≈ 0,9 : | 0,9 |
| 60 | | | | |
| 61 | specific consumption of Diesel generators (240-270 g/kWh): | | 240 | g/kWh |

Figure 9 (other entries)

The entries are now completed. Before you go to the results in the "Results" area, it is advisable to check all your entries again. In particular, you should ensure that all calculation values are valid (Column G).

3.4. Results

If you have finished making your entries, you can now read off the results of the calculation in this area. The results table (see Figure 10) is structured as follows:

First, it contains the conversion units, with the help of which fuel quantities, prices and the CO₂ emissions can be calculated from the energy quantities (Rows 64-68).

The bottom part of this table then contains the results for the US American and the European market. They are listed separately for the different categories and methods. The following details are given, from left to right for rows 70-75:

- Total energy consumption (column B-C)
- Total fuel consumption (column D-E)
- Costs per section and feet at installation (column F-I)

Including in rows 76-81 are the details of the CO₂ emissions. Details are also given, from left to right as follows:

- CO₂ emissions at manufacturing the liner (column B-C)
- CO₂ emission during transport of the liner from factory to building site (column D-E)
- CO₂ emission at installation (column F-G)

- Total CO₂ emissions per section (column H-I)

| | A | B | C | D | E | F | G | H | I |
|----|--|------------------------------------|---|------------------------------------|--|-------------------------|------------------------------------|------------------------------------|--------------|
| 63 | Results: | | | | | | | | |
| 64 | Energy capacity of fuel oil (Diesel) per liter: | | | | 10.68 kWh/ltr | | | | |
| 65 | specific consumption of Diesel generators: | | | | 240 g/kWh | | | | |
| 66 | specific weight of fuel oil (Diesel): | | | | 0.87 kg/ltr | | | | |
| 67 | 1 ltr = | | | | 0,2642 gallon | | | | |
| 68 | Carbon (CO ₂) equivalent when burning fuel oil (Diesel): | | | | 2,65 kg/ltr | | | | |
| 69 | | | | | | | | | |
| 70 | total heat quantity per section | | fuel oil + diesel per section | | costs per (only for fitting) | | | | |
| 71 | | | | | Europe | | USA | | |
| 72 | [kWh] | | [liters] [gallons] | | [€ per section] | [€/m] | [\$/ft] | [\$ per section] | |
| 73 | Water curing: | 75.108,60 kWh | 7.823,44 ltr | 2.066,95 gal | 6.501,79 € | 6,50 €/m | \$2,46/ft | \$8.061,11 | |
| 74 | Steam curing: | 13.313,13 kWh | 1.385,05 ltr | 365,93 gal | 1.149,59 € | 1,15 €/m | \$0,43/ft | \$1.427,13 | |
| 75 | UV-light curing: | 744,39 kWh | 216,16 ltr | 57,11 gal | 302,62 € | 0,30 €/m | \$0,07/ft | \$222,72 | |
| 76 | carbon emission per section (only manufacturing) | | carbon emission per section (only transportation) | | carbon emission per section (only fitting) | | total: carbon emission per section | | |
| 77 | Europe | USA | Europe | USA | Europe | USA | Europe | USA | |
| 78 | [kg CO ₂ equivalent] | [lbs CO ₂ equivalent] | [kg CO ₂ equivalent] | [lbs CO ₂ equivalent] | [kg CO ₂] | [lbs CO ₂] | [kg CO ₂ equivalent] | [lbs CO ₂ equivalent] | |
| 79 | Water curing: | 74980,1 kg | 165302,9 lbs | 625,5 kg | 1379,0 lbs | 20.732,1 kg | 45.706,5 lbs | 96337,7 kg | 212388,3 lbs |
| 80 | Steam curing: | 74980,1 kg | 165302,9 lbs | 625,5 kg | 1379,0 lbs | 3.670,4 kg | 8.091,8 lbs | 79276,0 kg | 174773,7 lbs |
| 81 | UV-light curing: | 104314,6 kg | 229974,4 lbs | 753,1 kg | 1660,2 lbs | 572,8 kg | 1.262,8 lbs | 105640,5 kg | 232897,4 lbs |

Figure 10 (Results)

If you want to save a calculation, you can do this easily under the menu function: File → Save as ... in Excel.

The application for calculating CO₂ emissions with this program is now finished.

For information about using other functions of the "Energy Calculator" please refer to section 4 on page 20.

4. Other functions

Apart from the CO₂ calculation for different installation methods, this program also provides other functions. These are shown on the other worksheets. There the "Input Data" (input mask) worksheet is followed not only by an overview of the methods considered here ("Calculation of all diameters") but also diagrams for displaying calculation results („Diagrams“; „Emission on site/ manufacturing/ total -kg, -oz, -%“).

In addition, there are more separate worksheets containing the tables for calculating the energy quantities and the CO₂ emissions for the methods. These contain all the calculation formulae respectively tables and represent the basis of the "Energy Calculator". However, this manual does not discuss these any further.

4.1. Overview (calculation all diameters)

The "Calculation of all diameters" worksheet provides a tabular overview of the 3 methods and all nominal pipe sizes from DN 150 - DN 1000 with selected wall thicknesses. It is used to compare the different methods and for comparison within a method. This overview provides information about energy consumption values, times, capacities of the curing equipment and CO₂ emissions. It uses data records from the "Input Data" worksheet (input mask), however, performs its own calculations independently of the energy calculation worksheets based on the input mask.

For improved orientation in the table, the upper area demarcates the various sections using different colors. The same colors are used as for the input mask. The table has the following structure: at the start there is a mask with input values. This is followed by the energy calculations for water, steam and UV light. At the end are the results for the CO₂ emissions.

Figure 11 shows the first part of the table, which is relevant for the user. Apart from the input data from the input mask, the various diameters DN 150 - 1000 with corresponding wall thicknesses are listed for synthetic non-woven and GRP liners.

| | A | B | C | D | E | F | G | H | I | J | K | L |
|----|--|--------|----------------------------|----------------|----------------|----------------------------|----------------|----------------------------|----------------|------------------------------------|---------------------------------------|-------------------------------|
| 2 | Data Input | | | | | | | | | | | |
| 3 | $ID_{\text{host pipe}} = OD_{\text{Liner}}$ (please enter in or mm only): | | | Wall thickness | | | | ID_{Liner} | | Amount of UV-lamps used for curing | Power of each UV-lamp used for curing | Power-Capacity of light train |
| 4 | | | | Felt Liners | UVA-GRP Liners | Felt Liners | UVA-GRP Liners | Felt Liners | UVA-GRP Liners | UVA-GRP Liners | | |
| 5 | data input | | resulting calculation data | data input | | resulting calculation data | | resulting calculation data | | data input | data input | resulting calculation data |
| 6 | [inch] | [mm] | [mm] | [mm] | [mm] | [m] | [m] | [m] | [m] | [n] | [W] | [W] |
| 7 | 6 | 150 | 0,150 m | 3 | 3,5 | 0,0030 m | 0,0035 m | 0,144 m | 0,143 m | 8 | 400 | 3200 |
| 8 | 8 | 200 | 0,200 m | 3 | 3,5 | 0,0030 m | 0,0035 m | 0,194 m | 0,193 m | 8 | 400 | 3200 |
| 9 | 9 | 225 | 0,225 m | 3,3 | 3,5 | 0,0033 m | 0,0035 m | 0,218 m | 0,218 m | 8 | 400 | 3200 |
| 10 | 10 | 250 | 0,250 m | 3,5 | 3,5 | 0,0035 m | 0,0035 m | 0,243 m | 0,243 m | 8 | 400 | 3200 |
| 11 | 12 | 300 | 0,300 m | 4,2 | 3,5 | 0,0042 m | 0,0035 m | 0,292 m | 0,293 m | 8 | 400 | 3200 |
| 12 | 14 | 350 | 0,350 m | 4,9 | 4 | 0,0049 m | 0,0040 m | 0,340 m | 0,342 m | 12 | 400 | 4800 |
| 13 | 15 | 375 | 0,375 m | 5,2 | 4 | 0,0052 m | 0,0040 m | 0,365 m | 0,367 m | 12 | 400 | 4800 |
| 14 | 16 | 400 | 0,400 m | 5,6 | 4 | 0,0056 m | 0,0040 m | 0,389 m | 0,392 m | 12 | 400 | 4800 |
| 15 | 18 | 450 | 0,450 m | 6,3 | 5 | 0,0063 m | 0,0050 m | 0,437 m | 0,440 m | 12 | 400 | 4800 |
| 16 | 20 | 500 | 0,500 m | 7 | 5 | 0,0070 m | 0,0050 m | 0,486 m | 0,490 m | 12 | 400 | 4800 |
| 17 | 22 | 550 | 0,550 m | 7,7 | 6 | 0,0077 m | 0,0060 m | 0,535 m | 0,538 m | 12 | 400 | 4800 |
| 18 | 24 | 600 | 0,600 m | 8,4 | 6 | 0,0084 m | 0,0060 m | 0,583 m | 0,588 m | 12 | 400 | 4800 |
| 19 | 26 | 650 | 0,650 m | 9,1 | 7 | 0,0091 m | 0,0070 m | 0,632 m | 0,636 m | 12 | 400 | 4800 |
| 20 | 27 | 675 | 0,675 m | 9,5 | 7 | 0,0095 m | 0,0070 m | 0,656 m | 0,661 m | 12 | 400 | 4800 |
| 21 | 28 | 700 | 0,700 m | 10 | 7 | 0,0100 m | 0,0070 m | 0,680 m | 0,686 m | 12 | 400 | 4800 |
| 22 | 30 | 750 | 0,750 m | 11 | 8 | 0,0110 m | 0,0080 m | 0,728 m | 0,734 m | 12 | 400 | 4800 |
| 23 | 32 | 800 | 0,800 m | 11,7 | 8 | 0,0117 m | 0,0080 m | 0,777 m | 0,784 m | 12 | 400 | 4800 |
| 24 | 36 | 900 | 0,900 m | 13,3 | 9 | 0,0133 m | 0,0090 m | 0,873 m | 0,882 m | 12 | 400 | 4800 |
| 25 | 40 | 1000 | 1,000 m | 14,6 | 10 | 0,0146 m | 0,0100 m | 0,971 m | 0,980 m | 12 | 400 | 4800 |

Figure 11 (Calculation all Diameters)

A structural calculation of the liners made of UP-GF (Berolina liner) and synthetic fiber laminate was performed to calculate the wall thicknesses. Please note that the information for non-woven liners involve theoretical, minimum details calculated by a program, while the wall thicknesses for GRP liners are taken from the product delivery data of BKP Berolina and recommendations of DIN and DWA.

After activating the full version, however, any other diameters can wall thicknesses can be entered for comparison purposes. These columns are labeled "data input" and have a yellow background. Further, this mask also contains an overview of the number of UV lamps and their output in watts in relation to the respective diameter. This information can also be adjusted to your own needs.

The rest of the table shows the detailed calculations for the methods and their results for the diameters DN 150 - DN 1000 and therefore merely has an informative character for the user.

4.2. Diagrams

Below the different diagrams are explained in detail.

For an explanation of the diagrams in the tab "Diagrams" read on in section 4.2.1.

For comments on the diagrams "Emission on site in kg, -oz, -%", "Emission manufacturing in kg, -oz, -%" and "Emission total in kg, -oz, -%" please proceed with section 4.2.2. continued on page 24.

4.2.1. "Diagrams"

The first bar chart (see Figure 12) illustrates for each relining method, the CO₂ content of the individual processes, making method comparable. The entire CO₂ emissions of each method is also displayed.

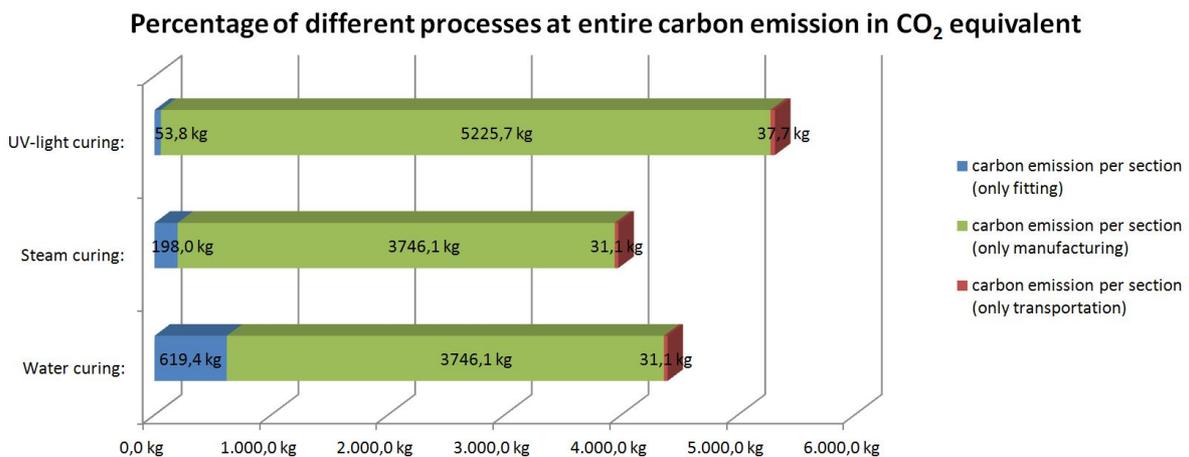


Figure 12 (Percentage of different processes at entire carbon emission)

The individual components are color-coded as follows:

- blue portion – emissions at installation
- green portion – emissions during manufacture
- red portion – emissions by transport

The amount of emissions related to the fixed section length.

At least you see 3 pie charts that illustrate percentage, about the share that has each process to the total emissions of each relining process. Again, the data refer to the specific section length.

Water curing

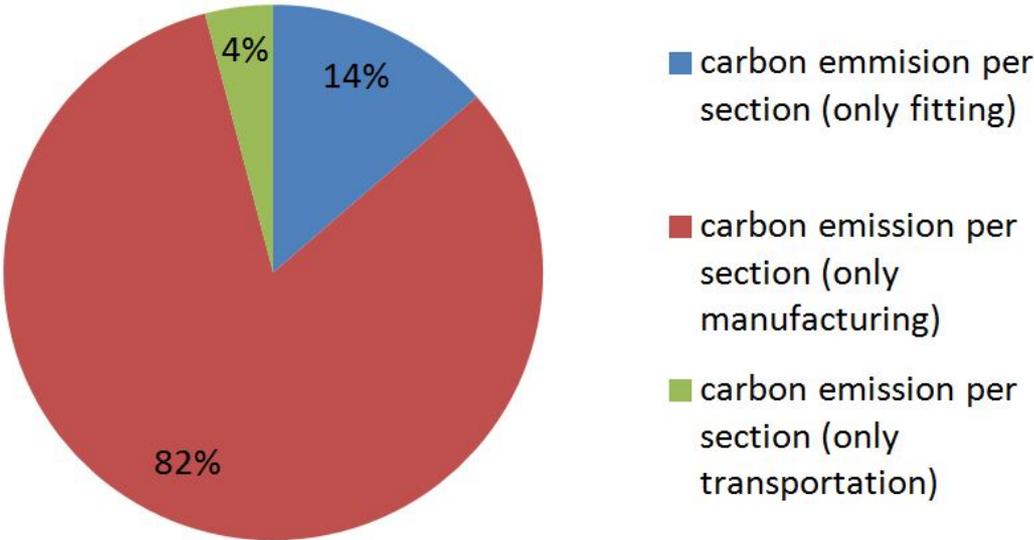


Figure 13 (Percentage at water curing)

In the figure above we see an example of the warm water curing. The individual processes are made in color as follows:

- blue portion – emissions at installation
- red portion – emissions during manufacture
- green portion – emissions by transport

The color scheme also applies for the other two methods.

4.2.2. “Emission on site/ manufacturing/ total -kg, -oz, -%“

The following line diagrams graphically illustrate the carbon dioxide emissions of the various methods and show how the individual methods perform relative to each other. The CO₂ emissions for nominal sizes ID 6 - ID 40 are shown. The data required for the display are taken from the "Calculation of all diameters" worksheet.

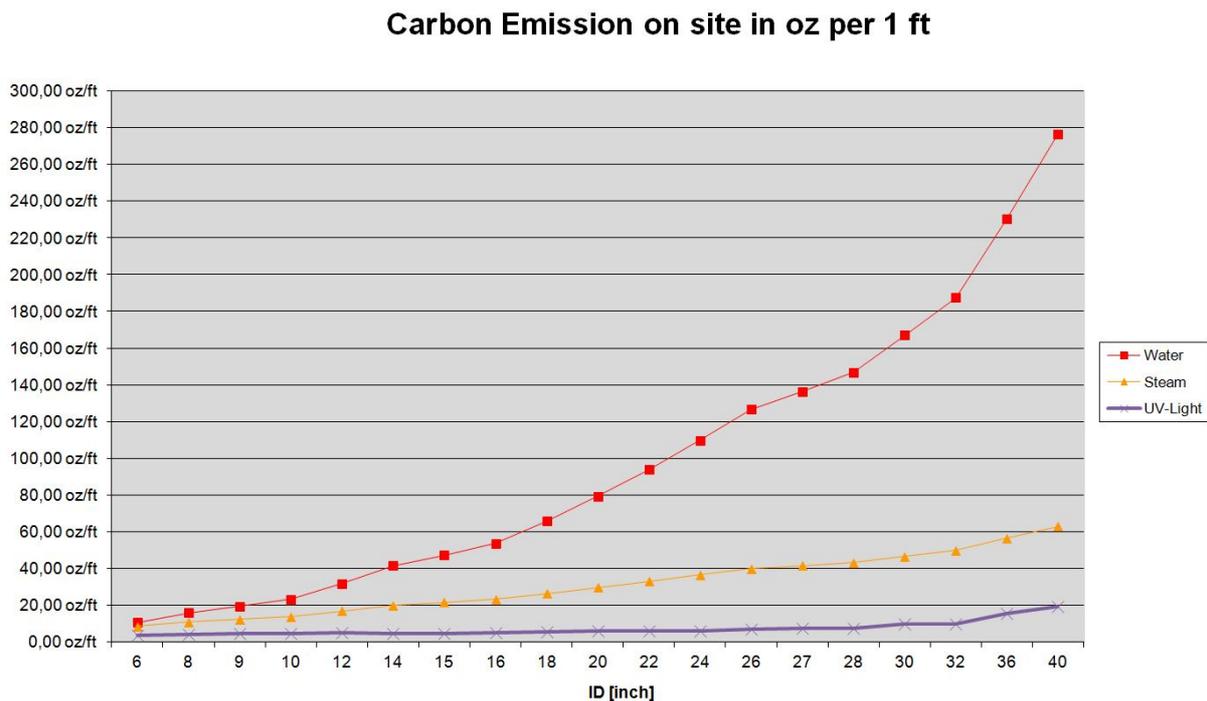


Figure 14 (Carbon emissions on site in oz per 1ft)

This diagram shows the carbon dioxide emissions in ounce per feet for the different methods and for diameters ID 6 – ID 40 (see Figure 14). This diagram also exists in kilograms per metre.

- *Red line - hot water curing*
- *Yellow line - steam curing*
- *Purple line - UV light curing*

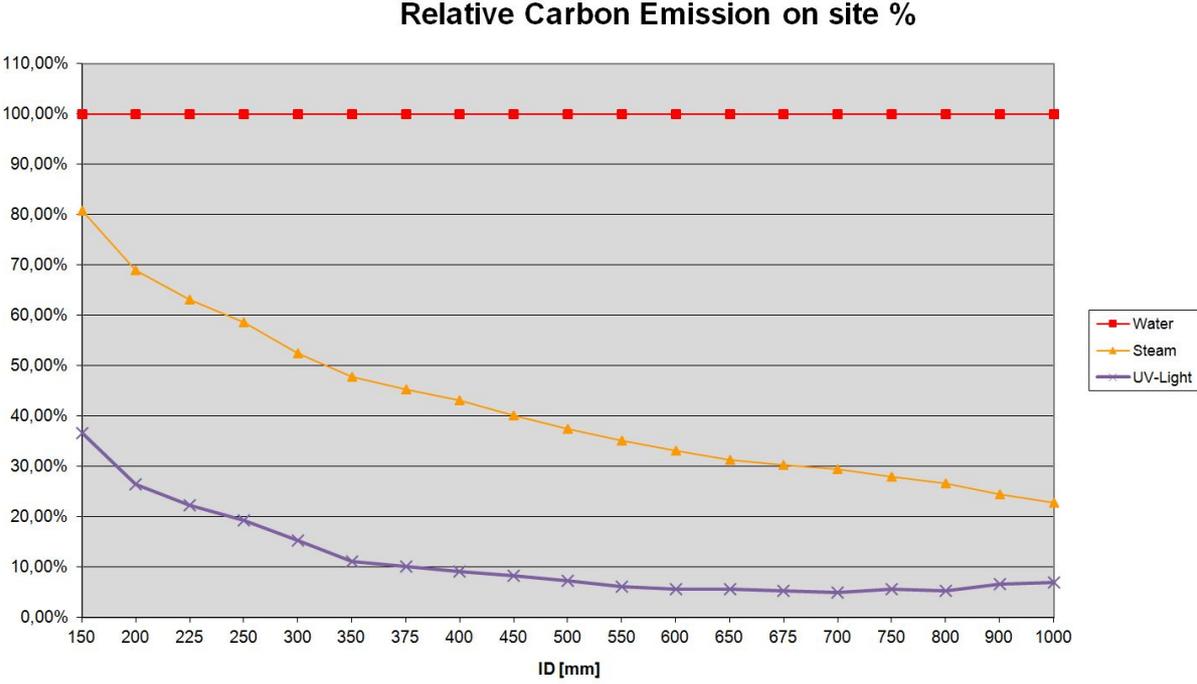


Figure 15 (Relative carbon emission on site in %)

The next line diagram (see Figure 15) shows how, under the same boundary conditions, the steam and UV curing method perform compared to hot water curing. To this end, the carbon dioxide emissions of hot water curing are set to 100%. The CO₂ emissions of steam and UV curing are therefore shown as a percentage of the hot water curing emissions. Also this chart refers only to the installation situation. In the following diagrams are explained, who regard the production and transport processes.

Carbon Emission at manufacturing in oz CO₂ equivalent per 1 ft

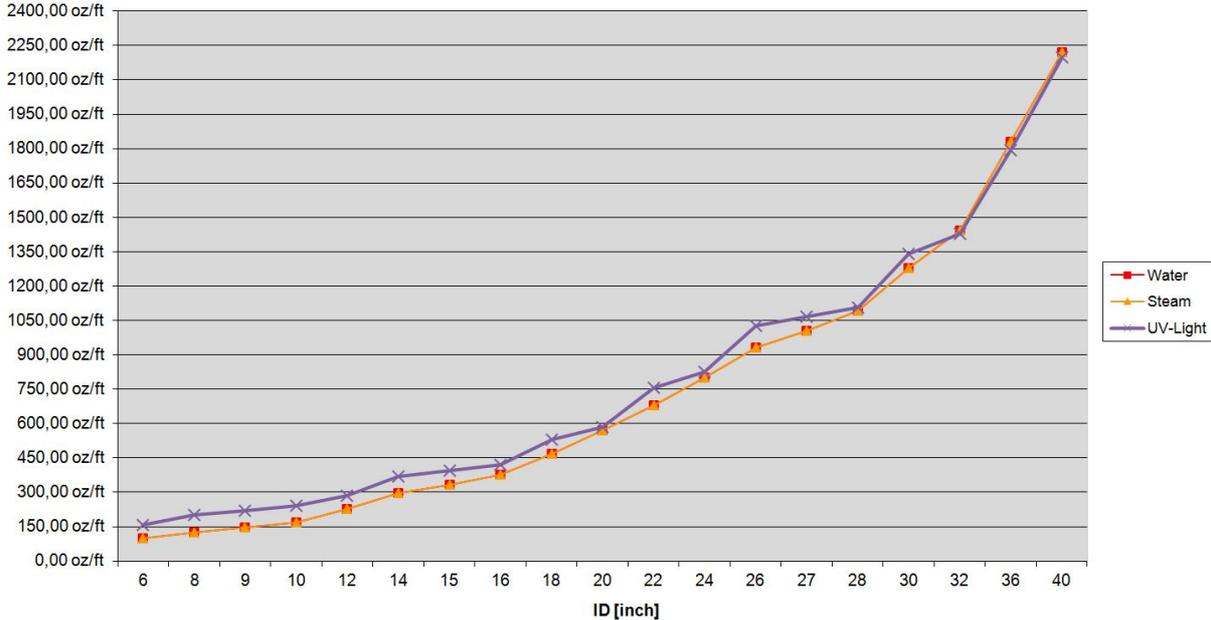


Figure 16 (Carbon emission at manufacturing in oz CO₂ equivalent per 1ft)

Figure 16 shows the carbon dioxide emissions resulting from the production and transportation of the liner in ounce per feet for various relining methods on the diameter of ID 6 – ID 40. This diagram also exists in kilograms per metre.

- *Red line - hot water curing*
- *Yellow line - steam curing*
- *Purple line - UV light curing*

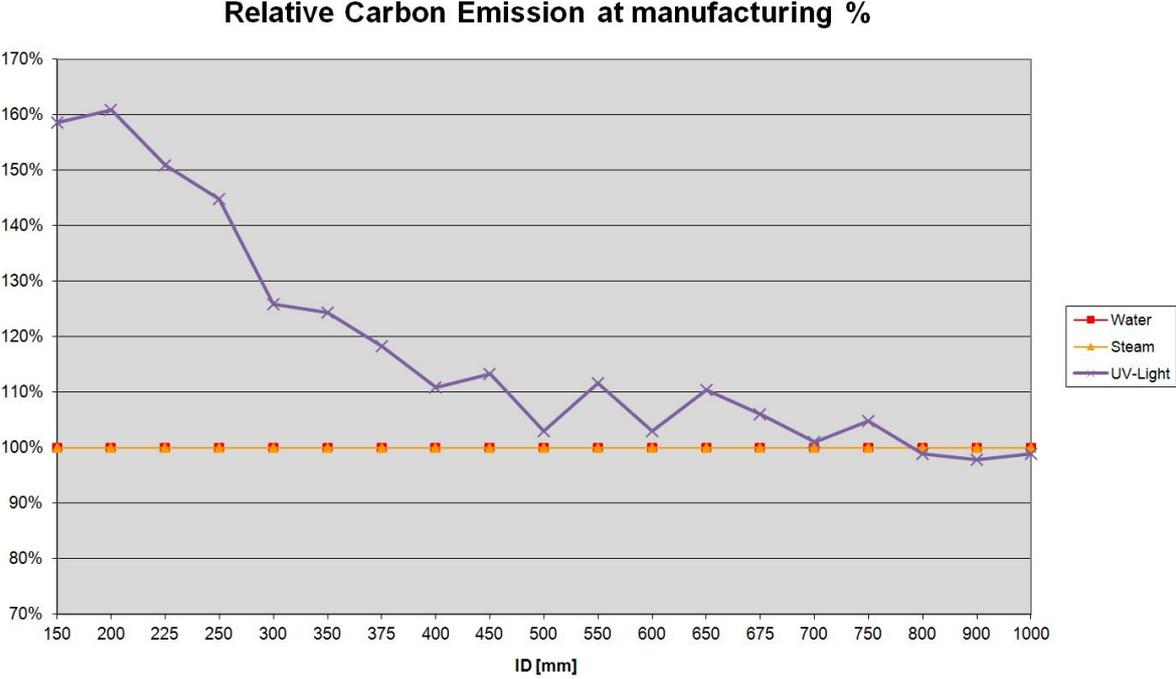


Figure 17 (Relative carbon emission at manufacturing in %)

The line diagram (see Figure 17) shows how, the GRP liner perform compared to the steam and hot water curing method, based on the emissions that occur during the production and transportation of the liner. To this end, the carbon dioxide emissions of the hot water and steam curing are set to 100%. The CO₂ emissions of UV curing are therefore shown as a percentage of the steam and hot water curing emissions.

The last diagrams (see Figure 18 and Figure 19) summarize the production emissions and the emissions incurred on the construction site. To follow all steps to the installation are considered. Figure 18 shows the total carbon dioxide emissions in ounce per feet for various relining methods on the diameter of ID 6 – ID 40. As in the previous diagrams this one also exists in kilograms per metre.

Total Carbon Emission in oz CO₂ equivalent per 1 ft

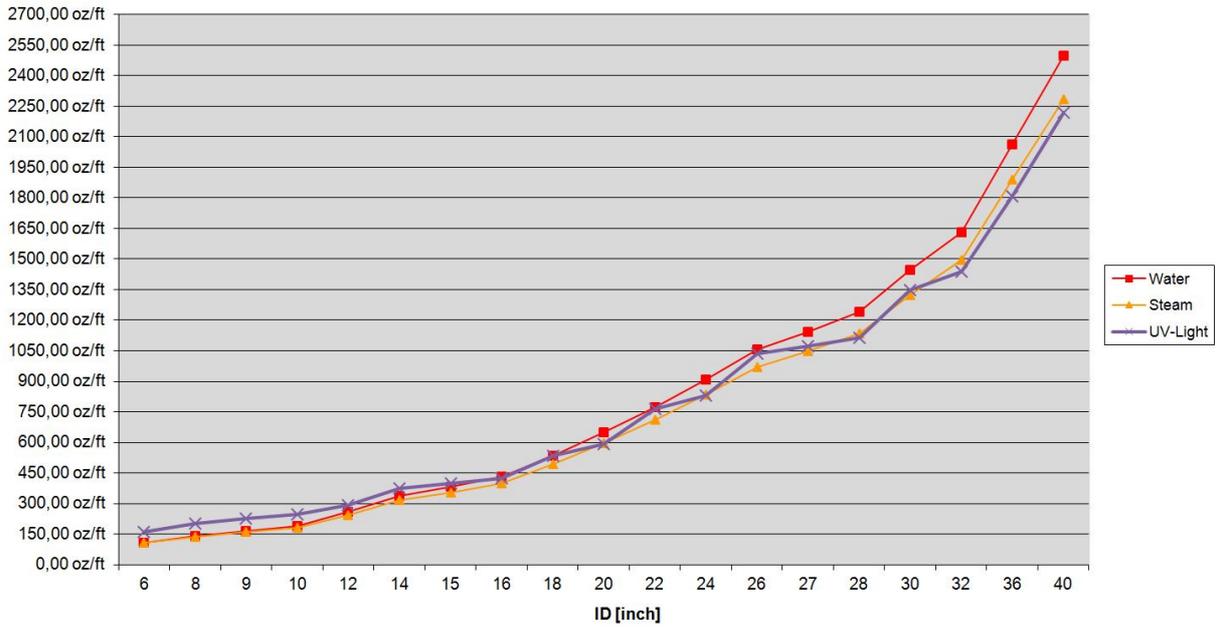


Figure 18 (Total carbon emission in oz CO₂ equivalent per 1ft)

The last diagram (see Figure 19) put the individual process in relation to each other. To this end, the carbon dioxide emissions of the hot water curing are set to 100%. The CO₂ emissions of UV and steam curing are therefore shown as a percentage of the hot water curing emissions.

Total Relative Carbon Emission %

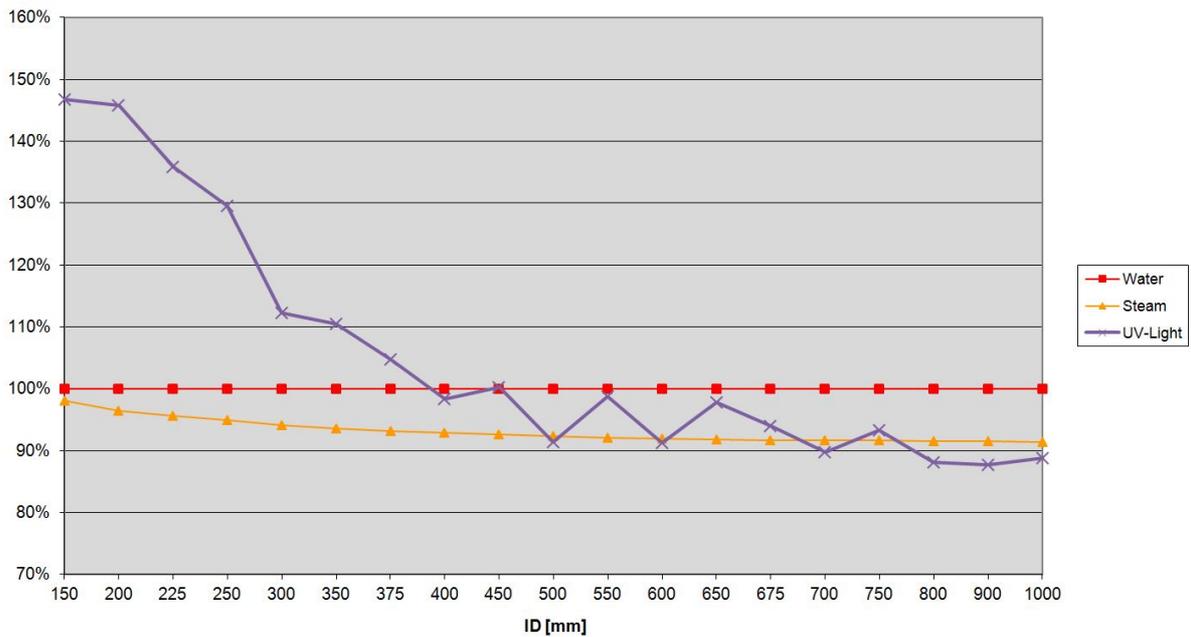


Figure 19 (Total relative carbon emission in %)

5. FAQs / Troubleshooting

1. What to do if the calculation value outputs "False"?

In this case, you should check the entry for the relevant parameter. This incorrect value can have different causes. First, ensure that you have entered the necessary input and that, where available, both input fields are not filled. Further, there are entries which are limited by certain requirements in the parameter description. This must also be checked.

2. What to do if the calculation value outputs "#Wert"?

In this case, text has been entered in the input field, in which a number is required.

3. What to do if the "Results" area contains the error value "#Wert!"?

This value is the consequence of an incorrect entry. Please check your entries in the input mask, by searching through the calculation values for errors. Column G will help you find the mistake. If "False" is in it, an input value is incorrect, and has to change.

4. What does the value "-----" mean?

This value is output if the input field for the capacity of the heater for hot water and steam curing is not filled. The consequence is that the program calculates using an idealized minimum size for the heater, which it determines from the energy calculation.

5. How can I perform the calculation with a heater chosen by me (with regard to heater output)?

This is possible both for the method with hot water curing (row 30) and steam curing (row 39). Simply enter the capacity of the required heater in the input field of the respective method. If this value now also appears on the right as a calculation value, the calculation is performed with the chosen heater.

6. Why are there 2 input fields for a parameter?

As the program is designed for international use, all inputs can be made using the US American system of units (column E) and the metric system (column F).

7. What to do if I have too little or even no information about the required input?

In such cases, we recommend making an engineering assumption in order to be able to continue with the input.

Authors:

Tom Küter and Christoph Klempert

from

Hochschule Wismar
Philipp-Müller-Straße 14
D-23966 Wismar
Telefon: 03841 / 753-0
Fax: 03841 / 753-73 83



with support from

WESSLING GmbH
Oststrasse 7
D-48341 Altenberge
Telefon: 02505 / 89-254
Fax: 02505 / 89-279



for

BKP Berolina Polyester GmbH & Co. KG
Heidering 28
D-16727 Velten
Telefon: 03304 / 20 88-100
Fax: 03304 / 20 88-110
E-Mail: info@bkp-berolina.de



SAERTEX multiCom GmbH
Brochterbecker Damm 52
D-48369 Saerbeck
Telefon: 02574 / 902-400
Fax: 02574 / 902-409
E-Mail: multicom@saertex.com



and



GERMAN SOCIETY FOR TRENCHLESS TECHNOLOGY E.V.

Deutsche Gesellschaft für grabenloses Bauen und Instandhalten von Leitungen e.V.

Messedamm 22, D – 14055 Berlin
Tel.: +49 30 3038-2143, Fax: 49 30 3038-2079
E-Mail: info@gstt.de, Internet: www.gstt.de