Carbon Spend Guidance Notes

Measuring and Managing Carbon Emissions in NRW Reduction Works

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Executive Summary

The Carbon Spend Guidance Notes outline the authors' preliminary ideas on how to measure, manage, and reduce carbon emissions linked to Non-Revenue Water (NRW) reduction efforts, which are essential for enhancing water utility infrastructure operations. As environmental concerns increasingly influence the planning and execution of infrastructure projects, it is vital for engineers, project managers, and sustainability professionals to understand the full carbon impact of their work. This Guidance Notes provide professionals with the necessary methodologies and tools to minimize carbon footprints while optimizing water system efficiency.

The Guidance Notes focuses on carbon spend, the total greenhouse gas emissions released, during works implementation, encompassing direct emissions from excavation equipment and indirect emissions from the supply chain. Additionally, it introduces the concept of avoided emissions, representing long-term carbon savings achieved through project outcomes such as improved water management and reduced energy consumption. By considering direct, indirect, and avoided emissions, the Guidance Notes helps stakeholders assess and minimize the environmental impact of their works and activities.

The core objectives of the Guidance Notes are:

- To identify key emission sources within NRW works and activities.
- To provide accurate methods for calculating carbon emissions from various excavation techniques, both manual and mechanical.
- To compare approaches based on their carbon efficiency.
- To develop effective strategies for reducing emissions while ensuring project success.
- To support informed, sustainable decision-making that promotes long-term water conservation and environmental benefits.

The Guidance Notes categorizes carbon emissions into three levels: **direct emissions** (from equipment and on-site activities), **indirect emissions** (from the supply chain and construction materials), and **avoided emissions** (from long-term efficiency gains such as reduced water loss and energy consumption). A detailed carbon calculation framework is presented, along with worked examples for Guidance Notes and mechanical excavation, transportation, and reinstatement activities.

To help minimize carbon spend, the Guidance Notes emphasizes practical strategies such as using low-emission machinery, optimizing logistics, sourcing local and recycled materials, and employing trenchless technologies to reduce excavation volumes. It also stresses the importance of adopting an iterative approach to carbon assessment, starting with standard calculations and refining them with site-specific data over time.

By following the guidance provided, stakeholders can make more informed decisions, ensuring that the carbon emissions "spent" on infrastructure improvements are outweighed by the long-term environmental benefits. The goal is to ensure that every tonne of carbon spent on reducing water losses results in significantly greater carbon savings through improved system efficiency, helping to create a more sustainable future for water utilities and their communities.

About the Authors

Stuart Hamilton

Stuart Hamilton is a distinguished and highly respected leader in the global water sector, with a career spanning over four decades. Currently, he serves as Vice President of the Caribbean Water and Wastewater Association (CWWA) and Chair of the International Water Association (IWA) Water Loss Specialist Group, in addition to leading the CWWA Caribbean Water Loss Specialist Group. His extensive experience and expertise have established him as a thought leader in the areas of water loss management, climate change mitigation, and sustainable water solutions.

An accomplished author, Stuart has made significant contributions to the field through numerous papers and the co-authorship of several influential books and manuals. His works include *"Unlocking the Potential: Physical Loss Reduction and Carbon Credits"* (2024) and *"Experiences from Performance-Based Non-Revenue Water Reduction Contracts"* (2025), building upon his previous landmark publications such as *"Improving Water Supply Networks – Fit for Purpose Strategies and Technologies"* (2021) and *"Leakage Detection"* (2020). These publications have provided crucial insights into innovative approaches to water loss control, NRW reduction, and their intersection with climate change mitigation, particularly through the lens of carbon credit calculation.

Stuart's qualifications are a testament to his expertise and commitment to environmental sustainability. He is a qualified Civil Engineer, a Chartered Environmentalist (CEnv), a Chartered Manager (CMgr), and a Fellow of the Chartered Institute of Water and Environmental Managers (FCIWEM). He also holds academic credentials from Northampton and Huntingdon universities in the UK, which have further shaped his understanding of water management and environmental systems.

Over the course of his career, Stuart has worked in more than 30 countries, delivering integrated, sustainable solutions across a wide range of projects. His areas of specialization include Project Management, Non-Revenue Water (NRW) Reduction, Climate Change Mitigation, and Strategic Leadership. He is also a recognized leader in the development and delivery of training programs that empower organizations and individuals to effectively tackle complex water management challenges.

Stuart is particularly renowned for his pioneering work in the field of carbon credit calculation, especially as it pertains to NRW reduction efforts. His innovative methodology has set new industry standards, offering valuable solutions to water utilities seeking to reduce water loss while contributing to global carbon reduction goals. This work aligns with his broader commitment to advancing environmental sustainability and creating lasting, positive change.

With a strong belief in the need for transformative action, Stuart is dedicated to fostering a balance between human activities and the natural environment. His advocacy for sustainable practices within the water sector continues to inspire global efforts to address climate change and improve water management systems. Stuart's ongoing contributions are shaping the future of climate resilience and sustainability, making him one of the most influential figures in water loss control and environmental stewardship today.

Bambos Charalambous

A Chartered Civil Engineer, Chartered Environmentalist, and Fellow of several distinguished professional organisations, Bambos brings over 45 years of diverse and deep expertise in the field of urban water distribution network management. His professional affiliations include being a Member of the Institution of Civil Engineers (UK), a Fellow of the Chartered Institution of Water and Environmental Management (UK), and a Fellow of the International Water Association (IWA).

Specializing in non-revenue water (NRW) and intermittent water supply (IWS), Bambos has developed a comprehensive skill set that applies to water utility efficiency programs, water audits, and innovative NRW reduction strategies. His extensive experience also spans the implementation of Performance-Based Contracts (PBC) aimed at sustainably reducing NRW, along with governance and capacity-building initiatives for water utilities worldwide.

Bambos's career includes 20 years as Technical Manager of a major Water Board, followed by 15 years as an international consultant and advisor. Throughout his career, he has worked on assignments across five continents, in more than 25 countries. His global perspective has shaped his ability to tackle complex water management issues, focusing not only on operational efficiency but also on the integration of sustainability into water utility practices.

In recent years, Bambos has expanded his focus to include innovative approaches in water loss reduction through Performance-Based Contracts and Carbon Emission Reduction. As an advocate for climate-resilient water management, his work emphasizes the importance of incorporating climate-conscious strategies into everyday water utility operations.

A key strength of Bambos's work lies in his holistic approach to addressing technical and operational challenges. He is skilled in setting clear, achievable goals and utilizing participatory methods to foster engagement, creativity, and awareness among utility staff. This approach has proven effective in improving operational performance and efficiency while fostering a culture of innovation and sustainability.

Bambos is a prominent figure in both academic and professional circles, having authored a wealth of influential papers and books on NRW, water loss, and urban water supply management. His recent co-authored works include *Unlocking the Potential: Physical Loss Reduction and Carbon Credits* (2024) and *Experiences from Performance-Based Non-Revenue Water Reduction Contracts* (2025), which build on his previous landmark publications, such as *Improving Water Supply Networks – Fit for Purpose Strategies and Technologies* (2021) and *Leakage Detection* (2020). These contributions have provided valuable insights into innovative solutions for water loss control, NRW reduction, and the integration of these issues with climate change mitigation, particularly in the context of carbon credit calculations.

His leadership extends beyond his consulting work, as he has served as Past Chair of the IWA's Water Loss Specialist Group and Intermittent Water Supply Specialist Group, a member of the IWA Strategic Council, and Past President of the Cyprus Water Association. Bambos continues to be a sought-after thought leader in the water management community, recognized for his expertise, global perspective, and passion for creating sustainable, climate-resilient water systems.

Disclaimer

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The methodologies and calculations included in this document are presented and are designed to be used in the absence of more specific data. Users are strongly encouraged to undertake detailed, locally informed analysis to ensure the accuracy and relevance of any calculations or assessments. Refining these processes using local data and contextual understanding is essential for producing meaningful and reliable results.

The authors would appreciate any feedback or corrections regarding any errors identified.

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1 October 2025 – Version 1

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1. Introduction

Managing carbon emissions has become a fundamental aspect of sustainable infrastructure practices. For water utilities, projects aimed at reducing Non-Revenue Water (NRW) and carrying out excavation activities for pipe repairs, replacements, or system upgrades often bring operational and environmental benefits. However, these projects also involve carbon emissions, which must be carefully accounted for. This carbon cost is referred to as **carbon spend**, the total greenhouse gas emissions released during project implementation.

This Guidance Notes provide detailed methodologies for understanding, calculating, and managing carbon spend in NRW reduction and relevant works activities. It covers carbon accounting methods, worked examples for excavation scenarios, and strategies for reducing carbon footprints. The aim is to assist engineers, project managers, and sustainability professionals with the tools they need to minimize environmental impacts while delivering water system improvements.

Objectives:
By following these Guidance Notes, you will be able to:

- Identify key emission sources in NRW and related work activities.
- Accurately calculate emissions from both manual and mechanical excavation methods.
- Evaluate and compare approaches based on carbon efficiency.
- Develop strategies to minimize carbon emissions while ensuring project success.
- Make informed decisions that ensure long-term sustainability and water conservation.

2. Levels of Carbon Emissions in NRW Reduction and Excavation Projects

Understanding the different levels of carbon emissions in infrastructure projects is crucial for accurately measuring and managing the environmental impact of water utility operations. Emissions can typically be categorized into **direct emissions**, **indirect emissions**, and **avoided emissions**. Each of these levels represents a different phase or aspect of the project lifecycle, and each carries its own set of opportunities for carbon reduction.

a. Direct Carbon Emissions

Direct emissions are those that are generated as a direct result of activities performed during the works execution phase. These emissions arise from the use of machinery, vehicles, and equipment on-site, as well as the energy consumed during the physical work. For excavation activities, this includes the carbon emissions from excavators, generators, and other heavy equipment used to dig, transport, and compact materials. For example, mechanical excavation produces significant direct emissions due to the diesel consumption of excavators and transport trucks. Similarly, the use of power tools during manual excavation, while lower in comparison, also generate direct emissions through the workers' energy expenditure and associated electricity consumption (if applicable). Reducing these emissions typically involves optimizing equipment efficiency, transitioning to low-emission machinery, or minimizing the duration and intensity of excavation work.

b. Indirect Carbon Emissions

Indirect emissions refer to those emissions that are associated with the supply chain and lifecycle of materials and services required for the execution of the work, but which occur outside the immediate operational scope. These emissions can be significant and often overlooked in early carbon assessments. For example, the carbon cost of manufacturing and transporting materials (such as pipes, backfill, or machinery) to the site, as well as the energy used to produce and deliver construction tools and other consumables, falls under indirect emissions. Additionally, any emissions generated by contractors' business operations, such as the energy consumed in offices or administrative processes, are also considered indirect. Indirect emissions are often harder to calculate and may require collaboration with suppliers and contractors to gather more precise data. However, this level of emissions offers a rich opportunity for reduction through practices such as sourcing local materials, using recycled products, or selecting low-carbon suppliers.

c. Avoided Carbon Emissions

Avoided emissions represent the carbon savings achieved through the successful implementation of work activities. In the context of NRW reduction, this refers to the reductions in emissions that are a result of a specific project's long-term impact on the water system's efficiency. For instance, when pipe replacement or leak detection activities are implemented, the resulting reduction in water losses leads to lower energy use for pumping, treatment, and transportation. This, in turn, reduces overall system carbon emissions. Similarly, improvements in system infrastructure, such as pressure management systems, can further reduce energy consumption and associated carbon emissions over the long term. These avoided emissions are a critical metric when assessing the overall environmental benefit of a project and justifying the carbon spend that may occur during the construction phase. Accurately quantifying avoided emissions requires a thorough understanding of a specific project's impact on water usage, energy efficiency, and system improvements.

d. Net Carbon Spend

Net carbon spend is the balance between the emissions generated by a specific project (direct and indirect emissions) and the emissions savings achieved through the improvements implemented by the project (avoided emissions).

A specific project is considered environmentally beneficial if the long-term reduction in operational carbon emissions outweigh the initial carbon spend associated with construction, excavation, and installation. In practice, this means that the carbon emissions "spent" during the project's implementation should be recovered through the project's effectiveness in reducing NRW and improving system performance over time.

The key to managing net carbon spend is accurate and thorough measurement of both the carbon cost and the carbon savings, with the goal of maximizing the latter while minimizing the former.

Each of these levels of carbon emissions represents an important aspect of carbon accounting in infrastructure work activities and projects. By understanding and managing emissions at each level, water utilities can take more informed, proactive steps toward achieving their sustainability goals, ensuring that the environmental impact of each project is minimized and the benefits are maximized.

For the calculations presented in this document and the associated matrix, we have focused on **direct emissions** and **indirect emissions** resulting from NRW related work activities. However, the emissions associated with office staff operations, have not been included nor accounted for the **avoided carbon emissions** that may result from long-term system improvements. Additionally, the emissions from the manufacturing of pipes, fittings, and equipment, as well as their embodied carbon (the carbon footprint from production and material sourcing), have not been factored into these calculations.

The reason for these omissions is that these elements require local, site-specific data and calculations to accurately assess their impact. There needs to be a clear boundary for the scope of these calculations, and in this document, we have intentionally limited our focus to the emissions directly related to the execution of the project itself. For a complete carbon assessment, stakeholders are encouraged to consider these additional factors using local data to ensure a more comprehensive carbon footprint analysis.

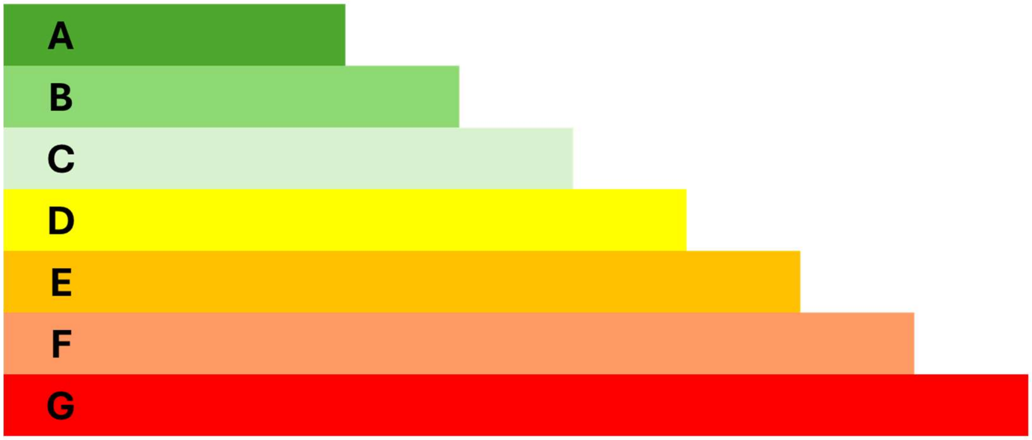
3. Carbon Efficiency Rating

The goal set by the authors is the design of a Carbon Efficiency Rating, for water loss related work activities to evaluate the carbon footprint associated with the management and reduction of NRW operational activities.

The Carbon Efficiency Rating will assess the carbon efficiency of various water loss reduction activities within water utility operations, such as leak detection, repair, pipe replacement, etc. By evaluating these activities against factors like energy consumption, resource use, and emissions from transportation and infrastructure, the rating identifies areas where carbon emissions can be reduced. It allows utilities to prioritize interventions that not only reduce water loss but also improve operational efficiency and sustainability. Ultimately, the Carbon Efficiency Rating provides a framework for optimizing both water conservation and carbon reduction efforts, helping utilities achieve environmental and economic goals. An example of a Carbon Efficiency Rating for Water Loss Reduction Work activities is shown in Figure 1. A n example of a possible Carbon Efficiency Rating is given below:

- **A**: < 30 kg CO2 eq. per activity
- **B**: 30-60 kg CO2 eq. per activity
- **C**: 60-120 kg CO2 eq. per activity
- **D**: 120-240 kg CO2 eq. per activity
- **E**: 240-480 kg CO2 eq. per activity
- **F**: 480-700 kg CO2 eq. per activity
- **G**: > 700 kg CO2 eq. per activity

Figure 1: Carbon Efficiency Rating for Waloss Reduction Activities



UNIT: xxx kg Eq CO_2/year

4. Understanding Carbon Spend

a. What is Carbon Spend?

Carbon Spend refers to the total carbon emissions generated during the implementation of a water loss reduction project. This includes both:

Direct emissions: Emissions from machinery, vehicles, and equipment used during construction.

Indirect emissions: Emissions related to manufacturing, transporting materials to the site, installation processes, and ongoing maintenance.

Even though a specific work activity may reduce energy consumption and consequently lower emissions in the water system, its implementation will still incur carbon emissions.

b. Why Carbon Spend Matters

Tracking and calculating carbon spend is critical for well-informed decision-making. By understanding the balance between emissions generated during project implementation and emissions saved through reduced NRW, stakeholders can ensure that the environmental benefits of the project exceed the costs.

For example:

Leak Detection Programs might have low carbon emissions from portable devices but result in significant net carbon savings by reducing water losses.

Pipe Replacement Projects might incur higher emissions due to energy-intensive processes but save significant water and energy, leading to a net benefit in the long term.

c. How Carbon Spend is Measured

Carbon Spend is typically expressed in: **Kilograms of CO_2 ($kgCO_2$)** for smaller projects or **Tonnes of CO_2 (tCO_2)** for larger projects.

A project is considered environmentally beneficial if the carbon savings from reduced water loss activities and improved system efficiency outweigh the carbon spend required for project implementation.

5. Emission Sources in NRW and Excavation Projects

a. Excavation Activities

Excavation, an essential activity in infrastructure maintenance, contributes significantly to carbon emissions.

Emissions arise from:

- **Manual excavation**: Emissions are tied to the physical energy exerted by workers.
- **Mechanical excavation**: Emissions are generated by machinery, such as excavators, which consume fuel.

b. Transport Requirements

Transport activities play a significant role in carbon emissions, including:

- **Transport of machinery**: Excavators and other heavy equipment are often transported to and from the site.
- **Crew transport**: Workers travel to and from the project site using light trucks or vans.
- **Material transport**: The delivery of backfill and other materials contributes to carbon emissions.

c. Restoration and Reinstatement

Once excavation is complete, the reinstatement process also contributes to emissions. This includes:

- **Backfilling**: The process of filling the excavated area with materials like soil or stone.
- **Compaction**: Machinery is used to compact the backfill and restore the surface.
- **Surface restoration**: Includes laying concrete, asphalt, or gravel to restore the surface.

Each of these activities carries a measurable carbon impact, depending on materials and methods used.

6. Carbon Emission Calculations

a. Assumptions and Local Adaptation

The carbon emission calculations and estimates presented throughout this Guidance Notes are based on globally accepted standard assumptions and general estimations derived from industry best practices. These values are intended to provide a useful baseline for those who lack specific, localized data or calculation models for their projects. While these estimates can serve as a starting point, it is highly recommended that each utility or contractor engage in more detailed, site-specific calculations wherever possible.

Local conditions, including variations in equipment efficiency, fuel types, transportation distances, and material choices, can all significantly affect the overall carbon footprint of a project. Therefore, stakeholders should seek to collect data pertinent to their own operations and project specifications to ensure the most accurate carbon spend calculations.

The calculations provided are meant to offer a preliminary framework, especially for teams who are new to carbon measurement or do not yet have access to tailored emission factors. These standard figures are designed to help project teams in the initial phase of measuring and understanding the carbon cost associated with various activities such as repairs, pipe installations, and system upgrades.

By leveraging these general estimates, users can begin to track and measure the environmental impact of their projects. As these projects progress, and more accurate data becomes available, it is encouraged to refine these initial calculations and replace standard values with real-world data for a more precise carbon footprint assessment.

This iterative process will not only support more sustainable decision-making but will also help to identify specific areas where emissions reduction efforts can be targeted for maximum impact.

The goal is to empower all project teams, regardless of their starting point, to engage meaningfully with carbon management and gradually build the capacity to perform more customized, accurate carbon assessments as part of their ongoing sustainability efforts.

b. Excavation Emissions

Manual Excavation:

A worker burns approximately **600 kcal/hour** when excavating soil and **1,000 kcal/hour** when working with harder materials like stone or concrete.

Conversions:

1 kcal = 0.00418 MJ

1 MJ = 0.000278 kWh

1 kWh = 0.1 kg CO_2

Example (Excavating 1 m^3 of soil for 2 hours):

Energy burned: 600 kcal/hour × 2 hours = 1,200 kcal

1,200 kcal × 0.00418 = 5.016 MJ

5.016 MJ × 0.000278 = 0.00139 kWh

0.00139 kWh × 0.1 = 0.000139 kg CO_2 per m^3.

Mechanical Excavation:

A typical medium excavator consumes about **20 L of diesel per hour**, with diesel having a carbon intensity of **2.68 kg CO_2/L**.

Example (Excavating for 0.5 hours):

Fuel consumption: 20 L × 0.5 hours = 10 L

Carbon emissions: 10 L × 2.68 kg CO_2/L = 26.8 kg CO_2.

c. Transport Emissions

Excavator Transport:

Emission factor: **0.5 kg CO_2/km**

Example (20 km round trip):

20 km × 0.5 kg CO_2/km = 10 kg CO_2.

Crew Transport:

Emission factor: **0.2 kg CO_2/km**

Example (20 km round trip):

20 km × 0.2 kg CO_2/km = 4 kg CO_2.

d. Restoration and Reinstatement Emissions

Backfilling:

Soil backfilling: **1.5 kg CO_2/m^3**

Stone backfilling: **2.25 kg CO_2/m^3**

Reinstatement (Concrete/Asphalt):

Reinstatement emissions: **4.02 kg CO_2/m^2**

7. Worked Scenarios

Scenario 1 – Manual Excavation in Soil (1 m^3)

Excavation: 0.000139 kg CO_2

Crew transport: 4.0 kg CO_2

Reinstatement (soil): 1.5 kg CO_2

Total emissions: **5.5 kg CO_2**

Scenario 2 – Mechanical Excavation in Soil (1 m^3)

Excavation: 26.8 kg CO_2

Excavator transport: 10.0 kg CO_2

Crew transport: 4.0 kg CO_2

Reinstatement (soil): 9.5 kg CO_2

Total emissions: **50.3 kg CO_2**

Scenario 3 – Mechanical Excavation in Concrete/Asphalt (1 m^3)

Excavation: 53.6 kg CO_2

Excavator transport: 10.0 kg CO_2

Crew transport: 4.0 kg CO_2

Reinstatement (imported backfill): 23.0 kg CO_2

Total emissions: **90.6 kg CO_2**

8. Strategies to Reduce Carbon Spend

To minimize the carbon footprint of water losses and excavation projects, consider the following strategies:

- **Maximize manual excavation** where feasible, especially for small-scale works.
- **Use low-emission machinery**, such as electric or hybrid excavators.
- **Optimize logistics** by reducing transport trips and combining delivery loads.
- **Source recycled or local materials** to reduce transportation and manufacturing emissions.
- **Use trenchless technologies** like pipe bursting, lining, or micro-tunneling to reduce excavation volumes.
- **Monitor and standardize emission reporting** across projects for consistent improvements.

9. Carbon Spend Examples

Examples of carbon spend on typical water loss reduction and operational activities are summarised in Table 1 and more analytical in Table 2**Error! Reference source not found.**.

The detailed calculations on how to estimate carbon spend for various work activities are presented in the Appendix.

Table 1: Examples of Carbon Spend

Work Description	Method of Work	Total Carbon Emissions (kg CO_2)		
		Ground Material		
		Soil	Stone	Concrete /Asphalt
Excavate in soil and renew stop tap / repair service pipe	Manual Excavation 1m x 1m x 1m	5.50	7.25	20.52
	Mechanical Excavation 1m x 1m x 1m	50.30	78.10	90.62
	Mechanical Excavation 2m x 1m x 1m	86.60	142.20	159.24
Excavate in soil and replace 1m of 20mm – 50mm service pipe *	Manual Excavation 1m x 1m x 0.3m	1.00	1.475	5.256
	Mechanical Excavation 1m x 1m x 0.3m	11.215	22.58	26.33
Excavate in soil and replace 1m of 75mm – 150mm main pipe *	Manual Excavation 1m x 1m x 0.3m	2.00	2.475	6.256
	Mechanical Excavation 1m x 1m x 0.3m	12.22	23.58	27.33
Water main repair 75mm – 150mm excavation	Manual Excavation - 2m x 1m x 1m	15.24	17.04	39.08
	Mechanical Excavation - 2m x 1m x 1m	94.64	150.24	167.28
Water Meter	Replace 15mm to 25mm no excavation required	2.00		
Water Meter Reading **	Per water meter read	0.02		
Leak Detection **	Per fitting listened on	0.02		

* It is estimated that a team on average will replace 8 metres of pipe per day and the carbons calculated above are per metre.

** It is estimated that a team on average will read 100 meters per day or listen on 100 fittings per day and the carbons calculated above are per meter read or per fitting listened on.

Table 2: Analytical Examples of Carbon Spend

	Stop tap renewal 1m x 1m x 1m - hand excavation				Stop tap renewal 1m x 1m x 1m mechanical excavation				Stop tap renewal / Service pipe repair 2m x 1m x 1m mechanical excavation			
	Soil	Stone Surface	Concrete Surface	Tarmac Surface	Soil	Stone Surface	Concrete Surface	Tarmac Surface	Soil	Stone Surface	Concrete Surface	Tarmac Surface
Kg/CO_2	5.5	7.25	20.52	20.52	50.3	78.1	90.62	90.62	86.6	142.2	159.24	159.24

	Service/Communication pipe repair 1m x 1m x 1m - hand excavation				Service/Communication pipe repair 1m x 1m x 1m - mechanical excavation				Service/Communication pipe repair 2m x 1m x 1m - mechanical excavation			
	Soil	Stone Surface	Concrete Surface	Tarmac Surface	Soil	Stone Surface	Concrete Surface	Tarmac Surface	Soil	Stone Surface	Concrete Surface	Tarmac Surface
Kg/CO_2	5.5	7.25	20.52	20.52	50.3	78.1	90.62	90.62	86.6	142.2	159.24	159.24

	Service/Communication pipe replacement per metre 1m x 1m x 0.3m - hand excavation				Service/Communication pipe replacement per metre 1m x 1m x 0.3m - mechanical excavation			
	Soil	Stone Surface	Concrete Surface	Tarmac Surface	Soil	Stone Surface	Concrete Surface	Tarmac Surface
Kg/CO_2	1	1.475	5.256	5.256	11.215	22.58	26.33	26.33

	75mm - 150mm pipe replacement per metre 1m x 1m x 0.3m - hand excavation				75mm - 150mm pipe replacement per metre 1m x 1m x 0.3m - mechanical excavation			
	Soil	Stone Surface	Concrete Surface	Tarmac Surface	Soil	Stone Surface	Concrete Surface	Tarmac Surface
Kg/CO_2	2	2.475	6.256	6.256	12.215	23.58	27.33	27.33

	75mm 150mm burst main repair with pump 2m x 1m x 1m - hand excavation				75mm - 150mm burst main repair with pump 2m x 1m x 1m - mechanical excavation			
	Soil	Stone Surface	Concrete Surface	Tarmac Surface	Soil	Stone Surface	Concrete Surface	Tarmac Surface
Kg/CO_2	15.24	17.04	39.08	39.08	94.64	150.24	167.28	167.28

	15mm - 25mm meter exchange no excavation required				Meter reading per read				Manual leak listening per fittings			
	Soil	Stone Surface	Concrete Surface	Tarmac Surface	Soil	Stone Surface	Concrete Surface	Tarmac Surface	Soil	Stone Surface	Concrete Surface	Tarmac Surface
Kg/CO_2	2	2	2	2	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

10. Conclusion

The **Carbon Spend Framework** ensures that sustainability remains central to Water Loss reduction and excavation activities. By accurately calculating both carbon emissions spent and saved, stakeholders can:

- Make informed decisions about project execution.
- Maximize carbon savings through improved system efficiency.
- Select environmentally friendly technologies and methods.

Every tonne of carbon spent on reducing water losses should yield significantly greater savings in carbon emissions, particularly through reduced energy consumption for water pumping, treatment, and supply. This Guidance Notes provide practitioners with the tools to ensure water reduction works and projects contribute positively to a sustainable future.

Appendix – Carbon Spend Calculations

1. Work Activity: Excavate in soil and renew stop tap / repair service pipe by hand 1m^3

Let us go over the process for **soil excavation**. We will calculate the carbon emissions related to:

Excavation (Manual Labour)

Travel to and from the excavation site

Reinstatement materials (for restoring the surface after the repair)

Step 1: Excavation (Manual Labour)

For **soil excavation**, digging will require less effort compared to **asphalt** or **concrete**, as soil is much softer.

Energy Expenditure for Digging Soil:

A person digging through **soil** typically burns around **600 kcal per hour** of physical effort.

For **2 hours** of digging, the total energy burned would be:

600 kcal/hour×2 hours=1,200 kcal600

Convert this to **megajoules (MJ)**:

1,200 kcal×0.00418=5.016 MJ

Convert to **kWh**:

5.016 MJ×0.000278=0.00139 kWh

Carbon emissions from manual labour:

0.00139 kWh×0.1=0.000139 kg CO_2

So, **carbon emissions from manual labour** for digging in soil are **0.000139 kg CO_2**.

Step 2: Travel to and From the Excavation Site

The travel emissions are the same as before because we're assuming the **same vehicle** for transport.

Assume a typical vehicle emits **0.2 kg CO_2 per kilometre**.

Let us assume the excavation site is **10 kilometres** away from the starting point (e.g., the office or depot), so the **round-trip distance** is **20 km**.

The carbon emissions from the vehicle's travel would be:

20 km×0.2 kg CO_2/km=4 kg CO_2

So, **carbon emissions from travel** are **4 kg CO_2**.

Step 3: Reinstatement Materials (for Surface Restoration)

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)

Activity	Manual (Hand Tools)
Soil/Stone compaction (reused)	0.5 kg CO_2
Hand Tools / Light Machinery compaction	1.0 kg CO_2

For reinstating the surface after the excavation, we'll assume that **soil backfilling** or **restoring the surface** involves **manual labour** and materials like **soil** or **gravel**.

Materials: Typically, the **carbon emissions** from the **backfilling materials** (soil, gravel, etc.) using existing excavated material with no imported materials can be estimated around **1.5 kg CO_2**. This includes **manual labour** for backfilling and compacting the surface.

So, **carbon emissions from reinstatement materials** are **1.5 kg CO_2**.

Total Carbon Emissions for Soil Excavation

Now let us add everything up:

11. Carbon from excavation (manual labour):
    - Labour: 0.000139 kg CO_2

12. Carbon from travel to and from the excavation site:
    - Travel emissions: 4 kg CO_2
13. Carbon from reinstatement materials (restoring the surface):
    - Reinstatement materials: 1.5 kg CO_2

Total Carbon Emissions: 0.000139 kg CO_2 + 4 kg CO_2 + 1.5 kg CO_2= **5.5 kg CO_2**

Final Answer:

The total carbon **used or emitted** for **excavating, traveling to and from the site, and reinstating the surface** (manual labour and materials) for a stop tap renewal / service pipe repair in **soil excavation** is approximately:

5.5 kg CO_2

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2. Work Activity: Excavate in stone and renew stop tap / repair service pipe by hand $1m^3$

For a **stone surface** (similar to digging through stone roads, gravel, or rocky ground), the excavation process will require significantly more energy than digging through soil.

Excavation (Manual Labour)

Travel to and from the excavation site

Reinstatement materials (for restoring the surface after the repair)

Step 1: Excavation (Manual Labour)

Since **stone** is a hard material to dig through, the energy expenditure for manual labour will be higher than soil.

Energy Expenditure for Digging Stone:

A person digging through **stone** typically burns about **1,000 kcal per hour** of strenuous physical activity (comparable to the effort required for breaking concrete).

For **2 hours** of digging, the total energy burned would be:

$1,000 \text{ kcal/hour} \times 2 \text{ hours} = 2,000 \text{ kcal}$

Convert to **megajoules (MJ)**:

$2,000 \text{ kcal} \times 0.00418 = 8.36 \text{ MJ}$

Convert to **kWh**:

$8.36 \text{ MJ} \times 0.000278 = 0.00232 \text{ kWh}$

Carbon emissions from manual labour:

0.00232 kWh×0.1=0.000232 kg CO_2

Hand Tools / Light Machinery for excavation	1.0 kg CO_2

So, **carbon emissions from manual labour** for digging through stone are **1.000232 kg CO_2**.

Step 2: Travel to and From the Excavation Site

We will assume the **same vehicle** and **distance** as before:

Assume a typical vehicle emits **0.2 kg CO_2 per kilometre**.

Round-trip distance is **20 km** (10 km each way to the site).

The **carbon emissions from travel** would be:

20 km×0.2 kg CO_2/km=4 kg CO_2

So, **carbon emissions from travel** are **4 kg CO_2**.

Step 3: Reinstatement Materials (for Surface Restoration)

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)

Activity	**Manual (Hand Tools)**
Soil/Stone compaction (reused)	0.5 kg CO_2
Hand Tools / Light Machinery compaction	1.0 kg CO_2

For **restoring the surface** after digging, we will assume that **backfilling** with materials like gravel or stone is required.

Materials: Typically, the **carbon emissions** from the **backfilling materials** (soil, gravel, etc.) using existing excavated material with no imported materials can be estimated around **1.5 kg CO_2**. This includes **manual labour** for backfilling and compacting the surface.

However, this will require granular compacted backfill which increases the reinstatement carbon impact by an extra 50% per 1m^3

So, **carbon emissions from reinstatement materials** are **2.25 kg CO_2**.

The **carbon emissions from reinstating to the surface** in stone will be around **2.25 kg CO_2**, which includes **manual labour** for compacting to the surface.

So, **carbon emissions from reinstatement materials** are **2.25 kg CO_2**.

Total Carbon Emissions for Stone Excavation

Now let us calculate the total carbon emissions:

- Carbon from excavation (manual labour):
    - Labour: 1.000232 kg CO_2
- Carbon from travel to and from the excavation site:
    - Travel emissions: 4 kg CO_2
- Carbon from reinstatement materials (restoring the surface):
    - Reinstatement materials: 2.25 kg CO_2

Total Carbon Emissions: 1.000232 kg CO_2+4 kg CO_2+2.25 kg CO_2=**7.250232 kg CO_2**

Final Answer:

The total carbon **used or emitted** for **excavating, traveling to and from the site, and reinstating the surface** (manual labour and materials) for a stop tap renewal/service pipe repair in a **stone surface** is approximately:

7.25 kg CO_2

---

3. Work Activity: Excavate in Concrete / Asphalt and renew stop tap / service pipe repair by hand 1m^3

For a **concrete / asphalt surface**, the excavation process will be even more energy-intensive than soil due to the **hardness** and **resistance** of concrete/asphalt. Let us go over the carbon emissions for:

Excavation (Manual Labour)

Travel to and from the excavation site

Reinstatement materials (for restoring the surface after the repair)

Step 1: Excavation (Manual Labour)

Digging through **concrete/asphalt** will require a lot of effort, especially if the surface is thick and reinforced. A person typically uses a **sledgehammer**, **pickaxe**, or similar tools, which are much more strenuous than tools used for digging through softer materials like soil.

Energy Expenditure for Digging Concrete/Asphalt:

A person digging through **concrete/asphalt** typically burns around **1,200 kcal per hour** due to the intensive physical work.

For **2 hours** of digging, the total energy burned would be:

1,200 kcal/hour×2 hours=2,400 kcal

Convert this to **megajoules (MJ)**:

2,400 kcal×0.00418=10.032 MJ

Convert to **kWh**:

10.032 MJ×0.000278=0.00279 kWh

Carbon emissions from manual labour:

0.00279 kWh×0.1=0.000279 kg CO_2

Hand Tools / Light Machinery excavation 1.0 kg CO_2

So, **carbon emissions from manual labour** for digging through concrete/asphalt are **1.000279 kg CO_2**.

Step 2: Travel to and From the Excavation Site

As before, we will assume the **same vehicle** and **distance**:

Assume a typical vehicle emits **0.2 kg CO_2 per kilometre**.

Round-trip distance is **20 km** (10 km each way to the site).

The **carbon emissions from travel** would be:

20 km×0.2 kg CO_2/km=4 kg CO_2

So, **carbon emissions from travel** are **4 kg CO_2**.

Step 3: Reinstatement Materials (for Surface Restoration)

For **concrete/asphalt**, restoring the surface will involve **backfilling** to **the surface** using stone prior to the top reinstatement.

Reinstatement (in Tarmac/Concrete)

The **reinstatement emissions for 1 metre in tarmac/concrete**:

4.02 kg CO_2 per meter

For **1 metre of reinstatement**, we multiply by 1:

4.02 kg CO_2×1=4.02 kg CO_2

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)

Activity	**Manual (Hand Tools)**
Transport of Imported Backfill	8.0 kg CO_2

Activity	Manual (Hand Tools)
Imported Backfill compaction (granular)	3.5 kg CO_2
Hand Tools / Light Machinery compaction	1.0 kg CO_2

Materials: Typically, the **carbon emissions** from the **backfilling materials with imported granular backfill** can be estimated around **3.5 kg CO_2.** This includes **manual labour** for backfilling and compacting the surface.

Transportation of imported backfill material and removal of old backfill can be estimated at **8 kg CO_2**.

So, **carbon emissions from reinstatement materials** are **15.52 kg CO_2**.

Total Carbon Emissions for Concrete Excavation

- Carbon from excavation (manual labour):
  - Labour: 1.000279 kg CO_2
- Carbon from travel to and from the excavation site:
  - Travel emissions: 4 kg CO_2
- Carbon from reinstatement materials (restoring the surface):
  - Reinstatement materials: 15.52 kg CO_2

Total Carbon Emissions:1.000279 kg CO_2+4 kg CO_2+15.52 kg CO_2=**20.520279 kg CO_2**

Final Answer:

The total carbon **used or emitted** for **excavating, traveling to and from the site, and reinstating the surface** (manual labour and materials) for a stop tap renewal / service pipe repair in a **concrete/asphalt surface** is approximately:

20.52kg CO_2

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4. Work Activity: Excavate and renew stop tap / repair service pipe in soil by mechanical excavator 1m^3

When using a **mechanical excavator** for the excavation of a stop tap renewal / service pipe repair, the **carbon emissions** from manual labour will be replaced by the emissions from the **excavator's fuel consumption** and other machinery-related factors.

Excavation (Mechanical Excavator)

Travel to and from the excavation site (for the excavator and transport vehicle)

Reinstatement materials (for restoring the surface after the repair)

Step 1: Excavation (Mechanical Excavator)

Excavator Efficiency:

A typical **excavator** can move approximately in soil **2.0m^3 of material per hour** on average, depending on the surface type, material hardness, and operator skill.

For **1m^3** of excavation:

1.0m^3/hour2m^3=0.5hours

So, the excavator will likely take about **0.5 hours** to excavate a **1m^3** hole.

Using an **excavator** will reduce the need for manual labour but introduce emissions from **fuel consumption**. A typical **diesel-powered excavator** has an average fuel consumption rate of about **15-25 litres per hour**, depending on its size and workload.

Fuel Consumption and Carbon Emissions for Excavator:

Let us assume a **medium-sized excavator** uses **20 litres of diesel per hour**.

The **carbon intensity** of diesel is about **2.68 kg CO_2 per litre**.

So, for **1 hours** of excavation:

20 litres/hour×.5 hours=10 litres

10 liters×2.68 kg CO_2/litre=26.8 kg CO_2

So, the **carbon emissions from the excavator** for **0.5 hours** of digging are approximately **26.8 kg CO_2**.

Step 2: Travel to and From the Excavation Site

The travel emissions will involve both the **excavator's transport** and a **van or light vehicle** for the crew. We will calculate the travel emissions for both separately:

Excavator Transport:

To transport the excavator typically emits **0.5 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.5 kg CO_2/km=10 kg

So, the **carbon emissions from transporting the excavator** are **10 kg CO_2**.

Crew Vehicle:

For the **crew vehicle**, we will use the same assumption of **0.2 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.2 kg CO_2/km=4 kg CO_2

So, the **carbon emissions from the crew vehicle** are **4 kg CO_2**.

Total Travel Emissions:

10 kg CO_2+4 kg CO_2=14 kg CO_2

So, the total **travel emissions** are **14 kg CO_2**.

Step 3: Reinstatement Materials (for Surface Restoration)

For **restoring the surface** after excavation, we will assume that the restoration involves **manual labour** and material is **soil**.

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)

Soil/Stone (reused)	0.5 kg CO_2
Hand Tools / Light Machinery	1.5 kg CO_2
Excavator Fuel (approx. 0.5 hrs)	7.5 kg CO_2

Reinstatement materials would generate **9.50 kg CO_2**, which includes **manual labour** for backfilling to the surface.

So, **carbon emissions from reinstatement materials** are **9.50 kg CO_2**.

Total Carbon Emissions for Excavation Using an Excavator

Let us now sum up the emissions:

- Carbon from excavation (mechanical excavator):
  - Excavator emissions: 26.8 kg CO_2
- Carbon from travel to and from the excavation site:
  - Travel emissions: 14 kg CO_2
- Carbon from reinstatement materials (restoring the surface):
  - Reinstatement materials: 9.50 kg CO_2
  -

Total Carbon Emissions: 26.8 kg CO_2+14 kg CO_2+9.5 kg CO_2=**50.3 kg CO_2**

Final Answer:

The total carbon **used or emitted** for **excavating, traveling to and from the site, and reinstating the surface** using a **mechanical excavator** for a stop tap renewal / service pipe repair in a **soil surface** is approximately:

50.3 kg CO_2

5. Work Activity: Excavate and renew stop tap / repair service pipe in Stone ground by mechanical excavator 1m^3

When using a **mechanical excavator** for the excavation for a stop tap renewal / service pipe repair, the **carbon emissions** from manual labour will be replaced by the emissions from the **excavator's fuel consumption** and other machinery-related factors. Let us break down the carbon emissions based on:

Excavation (Mechanical Excavator)

Travel to and from the excavation site (for the excavator and transport vehicle)

Reinstatement materials (for restoring the surface after the repair)

Step 1: Excavation (Mechanical Excavator)

Using an **excavator** will reduce the need for manual labour but introduce emissions from **fuel consumption**. A typical **diesel-powered excavator** has an average fuel consumption rate of about **15-25 litres per hour**, depending on its size and workload.

Excavator Efficiency:

A typical **excavator** can move approximately in stone **1.0m^3 of material per hour** on average, depending on the surface type, material hardness, and operator skill.

For **1m^3** of excavation:

1.0m^3/hour1m^3=1hours

So, the excavator will likely take about **1 hours** to excavate a **1m^3** hole.

Fuel Consumption and Carbon Emissions for Excavator:

Let us assume a **medium-sized excavator** uses **20 litres of diesel per hour**.

The **carbon intensity** of diesel is about **2.68 kg CO_2 per litre**.

So, for **1 hours** of excavation:

20 litres/hour×1 hours=20 litres

20 liters×2.68 kg CO_2/litre=53.6 kg CO_2

C**arbon emissions from the excavator** for **1 hour** of digging are approximately **53.6 kg CO_2.**

Step 2: Travel to and From the Excavation Site

The travel emissions will involve both the **excavator's transport** and a **van or light vehicle** for the crew. We will calculate the travel emissions for both separately:

Excavator Transport:

To transport the excavator typically emits **0.5 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.5 kg CO_2/km=10 kg

So, the **carbon emissions from transporting the excavator** are **10 kg CO_2**.

Crew Vehicle:

For the **crew vehicle**, we will use the same assumption of **0.2 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.2 kg CO_2/km=4 kg CO_2

So, the **carbon emissions from the crew vehicle** are **4 kg CO_2**.

Total Travel Emissions:

10 kg CO_2+4 kg CO_2=14 kg CO_2

So, the total **travel emissions** are **14 kg CO_2**.

Step 3: Reinstatement Materials (for Surface Restoration)

As in previous calculations, for **restoring the surface** after excavation, we will assume that the restoration involves **manual labour** and materials like **gravel stone**.

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)

Soil/Stone (reused)	0.5 kg CO_2
Hand Tools / Light Machinery compaction	1.5 kg CO_2
Excavator Fuel for backfilling	7.5 kg CO_2

Materials: Typically, the **carbon emissions** from the **backfilling materials** (soil, gravel, etc.) using existing excavated material with no imported materials can be estimated around **2.0 kg CO_2**. This includes **manual labour** for backfilling and compacting the surface.

However, this will require granular compacted backfill which increases the reinstatement carbon impact by an extra 50% per 1m^3

So, **carbon emissions from reinstatement materials** are **3.0 kg CO_2**.

Mechanical excavator for the backfilling is **7.5 kg CO_2**

The **carbon emissions from reinstating to the surface** (such as backfilling with stone will be around **10.5 kg CO_2**, which includes **manual labour** for compacting the surface.

So, **carbon emissions from reinstatement materials** are **10.5 kg CO_2**.

Total Carbon Emissions for Excavation Using an Excavator

Let us now sum up the emissions:

- Carbon from excavation (mechanical excavator):
  - Excavator emissions: 53.6 kg CO_2
- Carbon from travel to and from the excavation site:
  - Travel emissions: 14 kg CO_2
- Carbon from reinstatement materials (restoring the surface):
  - Reinstatement materials: 10.5 kg CO_2

Total Carbon Emissions: 53.6 kg CO_2+14 kg CO_2+10.5 kg CO_2= **78.1 kg CO_2**

Final Answer:

The total carbon **used or emitted** for **excavating, traveling to and from the site, and reinstating the surface** using a **mechanical excavator** for a stop tap renewal/service pipe repair in a **stone surface** is approximately:

78.1 kg CO_2

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6. Work Activity: Excavate and renew stop tap / repair service pipe in Concrete / Asphalt ground by mechanical excavator 1m^3

When using a **mechanical excavator** for the excavation for a stop tap renewal/service pipe repair, the **carbon emissions** from manual labour will be replaced by the emissions from the **excavator's fuel consumption** and other machinery-related factors.

Excavation (Mechanical Excavator)

Travel to and from the excavation site (for the excavator and transport vehicle)

Reinstatement materials (for restoring the surface after the repair)

Step 1: Excavation (Mechanical Excavator)

Excavator Efficiency:

A typical **excavator** can move approximately in stone **1.0m^3 of material per hour** on average, depending on the surface type, material hardness, and operator skill.

For **1m³** of excavation:

$1.0m^3/hour 1m^3=1 hours$

So, the excavator will likely take about **1 hour** to excavate a **1m³** hole.

Using an **excavator** will reduce the need for manual labour but introduce emissions from **fuel consumption**. A typical **diesel-powered excavator** has an average fuel consumption rate of about **15-25 litres per hour**, depending on its size and workload.

Fuel Consumption and Carbon Emissions for Excavator:

Let us assume a **medium-sized excavator** uses **20 litres of diesel per hour**.

The **carbon intensity** of diesel is about **2.68 kg CO_2 per litre**.

So, for **1 hour** of excavation:

20 litres/hour×1 hours=20 litres

20 liters×2.68 kg CO_2/litre=53.6 kg CO_2

So, the **carbon emissions from the excavator** for1 **hour** of digging are approximately **53.6 kg CO_2**.

Step 2: Travel to and From the Excavation Site

The travel emissions will involve both the **excavator's transport** and a **van or light vehicle** for the crew. We will calculate the travel emissions for both separately:

Excavator Transport:

To transport the excavator typically emits **0.5 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.5 kg CO_2/km=10 kg

So, the **carbon emissions from transporting the excavator** are **10 kg CO_2**.

Crew Vehicle:

For the **crew vehicle**, we will use the same assumption of **0.2 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.2 kg CO_2/km=4 kg CO_2

So, the **carbon emissions from the crew vehicle** are **4 kg CO_2**.

Total Travel Emissions:

10 kg CO_2+4 kg CO_2=14 kg CO_2

So, the total **travel emissions** are **14 kg CO_2**.

Step 3: Reinstatement Materials (for Surface Restoration)

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)

Activity	**With Excavator**
Transport of Imported Backfill	8.0 kg CO_2
Imported Backfill compaction (granular)	3.5 kg CO_2
Excavator Fuel for backfilling	7.5 kg CO_2

Materials: Typically, the **carbon emissions** from the **backfilling materials with imported granular backfill** can be estimated around **3.5 kg CO_2**. This includes **manual labour** for backfilling and compacting the surface.

Transportation of imported backfill material and removal of old backfill can be estimated at **8 kg CO_2**.

Excavator use **7.5 kg CO_2**.

For **concrete/asphalt**, restoring the surface will involve **backfilling** to **the surface** using stone prior to the top reinstatement.

Reinstatement (in Tarmac/Concrete)

The **reinstatement emissions for 1 metre in tarmac/concrete**:

4.02 kg CO_2 per meter

For **1 metre of reinstatement**, we multiply by 1:

4.02 kg CO_2×1=4.02 kg CO_2

Carbon emissions from reinstatement materials are

4.02 kg CO_2. + 3.5 kg CO_2. + 8 kg CO_2. + 7.5 kg CO_2. = 23.02 kg CO_2.

Total Carbon Emissions for Excavation Using an Excavator

Let us now sum up the emissions:

- Carbon from excavation (mechanical excavator):
  - Excavator emissions: 53.6 kg CO_2
- Carbon from travel to and from the excavation site:
  - Travel emissions: 14 kg CO_2
- Carbon from reinstatement materials (restoring the surface):
  - Reinstatement materials: 23.02 kg CO_2

Total Carbon Emissions: 53.6 kg CO_2+14 kg CO_2+23.02 kg CO_2=**90.62 kg CO_2**

Final Answer:

The total carbon **used or emitted** for **excavating, traveling to and from the site, and reinstating the surface** using a **mechanical excavator** for a stop tap renewal / service pipe rep in a **concrete/asphalt surface** is approximately:

90.62 kg CO_2

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7. Work Activity: Excavate and renew stop tap / repair service pipe by mechanical excavator 2m^3 in Soil

This result shows a significant increase in carbon emissions compared to manual labour due to the **excavator's fuel consumption** and the **transportation emissions** for the machinery and crew.

Excavating a larger hole 2x1x1

If we're now considering the excavation of a **2m^3** hole, we need to adjust the calculations to account for the **larger excavation volume**. Given that the **excavator** will be working for a longer period of time, we'll increase the time spent on excavation and adjust the emissions accordingly.

Let's go through the breakdown again for a **2m^3 excavation** using a mechanical excavator:

Step 1: Excavation (Mechanical Excavator)

A **2m^3 excavation** will take longer for the excavator compared to a 1m^3 excavation. We'll estimate the required time based on the volume of material being moved.

Excavator Efficiency:

A typical **excavator** can move approximately in soil **2.0m^3 of material per hour** on average, depending on the surface type, material hardness, and operator skill.

For **2m^3** of excavation:

2.0m^3/hour2m^3=1 hour

So, the excavator will likely take about **1 hours** to excavate a **2m^3** hole.

Fuel Consumption and Carbon Emissions:

As mentioned before, a **medium-sized diesel excavator** uses around **20 litres of diesel per hour**.

For **1 hour** of excavation:

20 litres/hour ×1 hours=20

20 litres × 2.68kg CO_2/litres=53.6kg CO_2

So, the **carbon emissions from the excavator** for **2 hours** of digging are approximately **53.6 kg CO_2**.

Step 2: Travel to and From the Excavation Site

The travel emissions will still involve both the **excavator's transport** and the **crew vehicle**.

Excavator Transport:

Excavator emits **0.5 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.5 kg CO_2/km=10 kg CO_2

C**arbon emissions from the excavator** are **10 kg CO_2.**

Crew Vehicle:

The **crew vehicle** emits **0.2 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.2 kg CO_2/km=4 kg CO_2

So, the **carbon emissions from the crew vehicle** are **4 kg CO_2**.

Total Travel Emissions:

10 kg CO_2+4 kg CO_2=14 kg CO_2

So, the total **travel emissions** remain **14 kg CO_2**.

Step 3: Reinstatement Materials (for Surface Restoration)

For **restoring the surface** after excavation, we will assume that the restoration involves **manual labour** and material is **soil**.

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)	
Soil/Stone (reused)	0.5 kg CO_2
Hand Tools / Light Machinery	1.5 kg CO_2
Excavator Fuel for backfilling	7.5 kg CO_2

Reinstatement would generate **9.50 kg CO_2**, which includes **manual labour** for backfilling to the surface.

Reinstatement 9.5 kg CO_2 x2 = 19 kg CO_2

Total carbon in the backfilling is **19 kg CO_2** = **19 kg CO_2**

Total Carbon Emissions for 2m^3 Excavation Using an Excavator

- Let's now sum up the emissions:
  - Carbon from excavation (mechanical excavator):
- Excavator emissions: 53.6 kg CO_2
  - Carbon from travel to and from the excavation site:
- Travel emissions: 14 kg CO_2
- Carbon from reinstatement materials (restoring the surface):
  - Reinstatement materials: 19.0 kg CO_2

Total Carbon Emissions: 53.6 kg CO_2+14 kg CO_2+19.0 kg CO_2=**86.6 kg CO_2**

Final Answer:

The total carbon **used or emitted** for **excavating, traveling to and from the site, and reinstating the surface** using a **mechanical excavator** for a **2m^3** excavation in a **soil surface** is approximately:

86.6 kg CO_2

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8. Work Activity: Excavate and renew stop tap / repair service pipe by mechanical excavator 2m^3 in stone.

This result shows a significant increase in carbon emissions compared to manual labour due to the **excavator's fuel consumption** and the **transportation emissions** for the machinery and crew.

Excavating a larger hole 2x1x1

If we're now considering the excavation of a **2m^3** hole, we need to adjust the calculations to account for the **larger excavation volume**. Given that the **excavator** will be working for a longer period of time, we'll increase the time spent on excavation and adjust the emissions accordingly.

Let's go through the breakdown again for a **2m^3 excavation** using a mechanical excavator:

Step 1: Excavation (Mechanical Excavator)

A **2m^3 excavation** will take longer for the excavator compared to a 1m^3 excavation. We'll estimate the required time based on the volume of material being moved.

Excavator Efficiency:

A typical **excavator** can move approximately **1.0m^3 of material per hour** on average, depending on the surface type, material hardness, and operator skill.

For **2m^3** of excavation:

1.0m^3/hour2m^3=2hours

So, the excavator will likely take about **2 hours** to excavate a **2m^3** hole.

Fuel Consumption and Carbon Emissions:

As mentioned before, a **medium-sized diesel excavator** uses around **20 litres of diesel per hour**.

For **2 hours** of excavation:

20 litres/hour×2 hours=40

40 liters×2.68kg CO_2/litres=107.2 kg CO_2

So, the **carbon emissions from the excavator** for **4 hours** of digging are approximately **107.2 kg CO_2**.

Step 2: Travel to and From the Excavation Site

The travel emissions will still involve both the **excavator's transport** and the **crew vehicle**.

Excavator Transport:

Excavator emits **0.5 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.5 kg CO_2/km=10 kg CO_2

C**arbon emissions from the excavator** are **10 kg CO_2**.

Crew Vehicle:

The **crew vehicle** emits **0.2 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.2 kg CO_2/km=4 kg CO_2

So, the **carbon emissions from the crew vehicle** are **4 kg CO_2**.

Total Travel Emissions:

10 kg CO_2+4 kg CO_2=14 kg CO_2

So, the total **travel emissions** remain **14 kg CO_2**.

Step 3: Reinstatement Materials (for Surface Restoration)

For **restoring the surface** after excavation, we will assume that the restoration involves **manual labour** and material is **stone**.

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)

Soil/Stone (reused)	0.5 kg CO_2
Hand Tools / Light Machinery	1.5 kg CO_2
Excavator Fuel for backfilling	7.5 kg CO_2

Materials: Typically, the **carbon emissions** from the **backfilling materials** using existing excavated material with no imported materials can be estimated around **2.0 kg CO_2**. This includes **manual labour** for backfilling and compacting the surface.

However, this will require stone compacted backfill which increases the reinstatement carbon impact by an extra 50% per 1m^3 so this is estimated to be 3.0 **kg CO_2**

Excavator for backfilling is **7.5 kg CO_2.**

Reinstatement total: **10.5 kg CO_2 x2 = 21 kg CO_2**

Total Carbon Emissions for 2m^3 Excavation Using an Excavator

Let's now sum up the emissions:

- Carbon from excavation (mechanical excavator):
  - Excavator emissions: 107.2 kg CO_2
- Carbon from travel to and from the excavation site:
  - Travel emissions: 14 kg CO_2
- Carbon from reinstatement materials (restoring the surface):
  - Reinstatement materials: 21 kg CO_2

Total Carbon Emissions:107.2 kg CO_2+14 kg CO_2+21 kg CO_2= **142.2 kg CO_2**

Final Answer:

The total carbon **used or emitted** for **excavating, traveling to and from the site, and reinstating the surface** using a **mechanical excavator** for a **2m^3** excavation in a **stone surface** is approximately:

142.2 kg CO_2

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9. Work Activity: Excavate and renew stop tap / repair service pipe by mechanical excavator 2m^3 in Concrete/Asphalt.

This result shows a significant increase in carbon emissions compared to manual labour due to the **excavator's fuel consumption** and the **transportation emissions** for the machinery and crew.

Excavating a larger hole 2x1x1

If we're now considering the excavation of a **2m^3** hole, we need to adjust the calculations to account for the **larger excavation volume**. Given that the **excavator** will be working for a longer period of time, we'll increase the time spent on excavation and adjust the emissions accordingly.

Let's go through the breakdown again for a **2m^3 excavation** using a mechanical excavator:

Step 1: Excavation (Mechanical Excavator)

A **2m^3 excavation** will take longer for the excavator compared to a 1m^3 excavation. We'll estimate the required time based on the volume of material being moved.

Excavator Efficiency:

A typical **excavator** can move approximately **1.0m^3 of material per hour** on average, depending on the surface type, material hardness, and operator skill.

For **2m^3** of excavation:

1.0m^3/hour2m^3=2hours

So, the excavator will likely take about **2 hours** to excavate a **2m^3** hole.

Fuel Consumption and Carbon Emissions:

As mentioned before, a **medium-sized diesel excavator** uses around **20 litres of diesel per hour**.

For **4 hours** of excavation:

20 litres/hour×2 hours=40

40 liters×2.68kg CO_2/litres=107.2kg CO_2

So, the **carbon emissions from the excavator** for **4 hours** of digging are approximately **107.2 kg CO_2**.

Step 2: Travel to and From the Excavation Site

The travel emissions will still involve both the **excavator's transport** and the **crew vehicle**.

Excavator Transport:

Excavator emits **0.5 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.5 kg CO_2/km=10 kg CO_2

C**arbon emissions from the excavator** are **10 kg CO_2.**

Crew Vehicle:

The **crew vehicle** emits **0.2 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.2 kg CO_2/km=4 kg CO_2

So, the **carbon emissions from the crew vehicle** are **4 kg CO_2**.

Total Travel Emissions:

10 kg CO_2+4 kg CO_2=14 kg CO_2

So, the total **travel emissions** remain **14 kg CO_2.**

Step 3: Reinstatement Materials (for Surface Restoration)

The reinstatement materials backfilling with imported backfill. So, the emissions from the materials used to restore to just below the surface will be:

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)

Activity	**With Excavator**
Transport of Imported Backfill	8.0 kg CO_2 - this is regardless of m^3 delivered
Imported Backfill compaction (granular)	3.5 kg CO_2
Excavator Fuel for backfilling	7.5 kg CO_2

Materials: Typically, the **carbon emissions** from the **backfilling materials with imported granular backfill** can be estimated around **3.5 kg CO_2**. This includes **manual labour** for backfilling and compacting the surface.

Transportation of imported backfill material and removal of old backfill can be estimated at **8 kg CO_2**.

Excavator uses **7.5 kg CO_2**.

Reinstatement is **3.5 kg CO_2 + 8 kg CO_2** + **7.5 kg CO_2** = 19 **kg CO_2**

Total 19 **kg CO_2 x 2 = 38 kg CO_2 - 8 kg CO_2 = 30 kg CO_2**

For **concrete/asphalt**, restoring the surface will involve **backfilling** to **the surface** using stone prior to the top reinstatement.

Reinstatement (in Tarmac/Concrete)

The **reinstatement emissions for 1 metre in tarmac/concrete**:

4.02 kg CO_2 per meter

For **2 metres of reinstatement**, we multiply by 2:

4.02 kg CO_2×2=8.04 kg CO_2

Carbon emissions from reinstatement materials are

8.04 kg CO_2 + 38 kg CO_2 = 46.04 kg CO_2.

Total Carbon Emissions for 2m^3 Excavation Using an Excavator

Let's now sum up the emissions:

- Carbon from excavation (mechanical excavator):
  - Excavator emissions: 107.2 kg CO_2
- Carbon from travel to and from the excavation site:
  - Travel emissions: 14 kg CO_2
- Carbon from reinstatement materials (restoring the surface):
  - Reinstatement materials: 38.04 kg CO_2

Total Carbon Emissions: 107.2 kg CO_2+14 kg CO_2+46.04 kg CO_2=**159.24 kg CO_2**

Final Answer:

The total carbon **used or emitted** for **excavating, traveling to and from the site, and reinstating the surface** using a **mechanical excavator** for a **2m^3** excavation in a **concrete/asphalt surface** is approximately:

159.24 kg CO_2

---

10. Work Activity: Excavate in soil and replace 1m of 20mm – 50mm service pipe excavating by hand 1m x 1m x 0.3m

Let us go over the same process for **soil excavation**. We will calculate the carbon emissions related to:

Excavation (Manual Labour)

Travel to and from the excavation site

Reinstatement materials (for restoring the surface after the repair)

Step 1: Excavation (Manual Labour)

For **soil excavation**, digging will require less effort compared to **asphalt** or **concrete**, as soil is much softer.

Energy Expenditure for Digging Soil:

A person digging through **soil** typically burns around **600 kcal per hour** of physical effort.

For **2 hours** of digging, the total energy burned would be:

600 kcal/hour×2 hours=1,200 kcal600

Convert this to **megajoules (MJ)**:

1,200 kcal×0.00418=5.016 MJ

Convert to **kWh**:

5.016 MJ×0.000278=0.00139 kWh

Carbon emissions from manual labour:

0.00139 kWh×0.1=0.000139 kg CO_2

To excavate a trench 1x1x.3m^3

0.000139 x 0.3 = .0000463

So, **carbon emissions from manual labour** for digging in 0.3m^3soil is **0.0000463 kg CO_2**.

Step 2: Travel to and From the Excavation Site

Next, we need to calculate the emissions from travel to and from the site. Let's assume a typical **van or light vehicle** is used for transportation.

Assume a typical vehicle emits about **0.2 kg CO_2 per kilometre** (this is a typical figure for a medium-sized van).

Let us assume the excavation site is **10 kilometres** away from the starting point (e.g., the office or depot).

Crew Vehicle:

The **crew vehicle** emits **0.2 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.2 kg CO_2/km=4 kg CO_2

So, the **carbon emissions from the crew vehicle** are **4 kg CO_2**.

Total Travel Emissions:

So, the total **travel emissions** for 1 full 8-hour day are **4 kg CO_2**.

As we are calculating per metre and it only takes 0.3 hrs to excavate 1m length then this is reduced to approximately 87.5%

So total travel emissions per 1m of excavation is 4 kg CO_2 *12.5% = **0.5 kg CO_2.**

Step 3: Reinstatement Materials (for Surface Restoration)

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)

Activity	**Manual (Hand Tools)**
Soil compaction (reused)	0.5 kg CO_2
Hand Tools / Light Machinery compaction	1.0 kg CO_2

or reinstating the surface after the excavation, we'll assume that **soil backfilling** or **restoring the surface** involves **manual labour** and materials like **soil** or **gravel**.

Materials: Typically, the **carbon emissions** from the **backfilling materials** (soil, gravel, etc.) using existing excavated material with no imported materials can be estimated around **1.5 kg CO_2**. This includes **manual labour** for backfilling and compacting the surface.

For a trench of 1m x m1 x 0.3m

1.5 kg CO_2 x 0.3 = 0.5 kg CO_2

So, **carbon emissions from reinstatement materials** are **0.5 kg CO_2**.

Step 4: Pipe Transport Emissions

The 20mm – 50mm pipe will be carried in the team vehicle so no transport for pipe is required

---

Total Carbon Emissions for Soil Excavation

Now let us add everything up:

- Carbon from excavation (manual labour):
  - Labour: 0.0000463 kg CO_2
- Carbon from travel to and from the excavation site:
  - Travel emissions: 0.5 kg CO_2
- Carbon from reinstatement materials (restoring the surface):
  - Reinstatement materials: 0.5 kg CO_2

Total Carbon Emissions: 0.000463 kg CO_2 + 0.5 kg CO_2 + 0.5 kg CO_2 = **1.000463**

Final Answer:

The total carbon **used or emitted** for **excavating, traveling to and from the site, and reinstating the surface** (manual labour and materials) for installation of 1m of service pipe in **soil excavation** is approximately:

1 kg CO_2

---

11. Work Activity: Excavate in stone and install 1m of 20mm – 50mm service pipe by hand 1m x 1m x 0.3m

For a **stone surface** (similar to digging through stone roads, gravel, or rocky ground), the excavation process will require significantly more energy than digging through soil.

Excavation (Manual Labour)

Travel to and from the excavation site

Reinstatement materials (for restoring the surface after the repair)

Step 1: Excavation (Manual Labour)

Since **stone** is a hard material to dig through, the energy expenditure for manual labour will be higher than soil.

Energy Expenditure for Digging Stone:

A person digging through **stone** typically burns about **1,000 kcal per hour** of strenuous physical activity (comparable to the effort required for breaking concrete).

For **2 hours** of digging, the total energy burned would be:

1,000 kcal/hour×2 hours=2,000 kcal

Convert to **megajoules (MJ)**:

2,000 kcal×0.00418=8.36 MJ

Convert to **kWh**:

8.36 MJ×0.000278=0.00232 kWh

Carbon emissions from manual labour:

0.00232 kWh×0.1=0.000232 kg CO_2

Hand Tools / Light Machinery for excavation 1.0 kg CO_2

To excavate a trench 1m x 1m x 0.3m

1.000232 x 0.3 = 0.3 kg CO_2

So, **carbon emissions from manual labour** for digging through stone are **0.3 kg CO_2**.

Step 2: Travel to and From the Excavation Site

Next, we need to calculate the emissions from travel to and from the site. Let's assume a typical **van or light vehicle** is used for transportation.

Assume a typical vehicle emits about **0.2 kg CO_2 per kilometre** (this is a typical figure for a medium-sized van).

Let us assume the excavation site is **10 kilometres** away from the starting point (e.g., the office or depot).

Crew Vehicle:

The **crew vehicle** emits **0.2 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

$20\ km \times 0.2\ kg\ CO_2/km = 4\ kg\ CO_2$

So, the **carbon emissions from the crew vehicle** are **4 kg CO_2**.

Total Travel Emissions:

So, the total **travel emissions** for 1 full 8-hour day are **4 kg CO_2**.

As we are calculating per metre and it only takes 0.3 hrs to excavate 1m length then this is reduced to approximately 87.5%

So total travel emissions per 1m of excavation is 4 kg CO_2 *12.5% = **0.5 kg CO_2.**

Step 3: Reinstatement Materials (for Surface Restoration)

Carbon Emissions Table (kg CO_2 per $1m^3$ backfill only)

Activity	**Manual (Hand Tools)**
Soil/Stone compaction (reused)	0.5 kg CO_2
Hand Tools / Light Machinery compaction	1.0 kg CO_2

For **restoring the surface** after digging, we will assume that **backfilling** with materials like gravel or stone is required.

Materials: Typically, the **carbon emissions** from the **backfilling materials** (soil, gravel, etc.) using existing excavated material with no imported materials can be estimated around **1.5 kg CO_2**. This includes **manual labour** for backfilling and compacting the surface.

However, this will require granular compacted backfill which increases the reinstatement carbon impact by an extra 50% per $1m^3$

So, **carbon emissions from reinstatement materials** are **2.25 kg CO_2**.

The **carbon emissions from reinstating to the surface** in stone will be around **2.25 kg CO_2**, which includes **manual labour** for compacting to the surface.

To backfill a trench 1m x 1mm x 0.3m

2.25 **kg CO_2** x 0.3 = 0.675

So, **carbon emissions from reinstatement materials** are **0.675 kg CO_2**.

Step 4: Pipe Transport Emissions

The 20mm – 50mm pipe will be carried in the team vehicle so no transport for pipe is required

---

Total Carbon Emissions for Stone Excavation

Now let us calculate the total carbon emissions:

- Carbon from excavation (manual labour):
  - Labour: 0.3 kg CO_2
- Carbon from travel to and from the excavation site:
  - Travel emissions: 0.5 kg CO_2
- Carbon from reinstatement materials (restoring the surface):
  - Reinstatement materials: 0.675 kg CO_2

Total Carbon Emissions: 0.3 kg CO_2+ 0.5 kg CO_2+ 0.675 kg CO_2= **1.475 kg CO_2**

Final Answer:

The total carbon **used or emitted** for **excavating, traveling to and from the site, and reinstating the surface** (manual labour and materials) for installation of 1m of 20mm – 50mm service pipe in a **stone surface** is approximately:

1.475 kg CO_2

---

12. Work Activity: Excavate in concrete / asphalt and install 1m of 20mm – 50mm service pipe by hand 1m x 1m x 0.3m

For a **concrete / asphalt surface**, the excavation process will be even more energy-intensive than soil due to the **hardness** and **resistance** of concrete/asphalt. Let us go over the carbon emissions for:

Excavation (Manual Labour)

Travel to and from the excavation site

Reinstatement materials (for restoring the surface after the repair)

Step 1: Excavation (Manual Labour)

Digging through **concrete/asphalt** will require a lot of effort, especially if the surface is thick and reinforced. A person typically uses a **sledgehammer**, **pickaxe**, or similar tools, which are much more strenuous than tools used for digging through softer materials like soil.

Energy Expenditure for Digging Concrete/Asphalt:

A person digging through **concrete/asphalt** typically burns around **1,200 kcal per hour** due to the intensive physical work.

For **2 hours** of digging, the total energy burned would be:

1,200 kcal/hour×2 hours=2,400 kcal

Convert this to **megajoules (MJ)**:

2,400 kcal×0.00418=10.032 MJ

Convert to **kWh**:

10.032 MJ×0.000278=0.00279 kWh

Carbon emissions from manual labour:

0.00279 kWh×0.1=0.000279 kg CO_2

Hand Tools / Light Machinery excavation 1.0 kg CO_2

For a trench of 1m x 1m x 0.3m

1.000279 kg CO_2 x 0.3 = 0.3 kg CO_2

So, **carbon emissions from manual labour** for digging through concrete/asphalt are **0.3 kg CO_2**.

Step 2: Travel to and From the Excavation Site

Next, we need to calculate the emissions from travel to and from the site. Let's assume a typical **van or light vehicle** is used for transportation.

Assume a typical vehicle emits about **0.2 kg CO_2 per kilometre** (this is a typical figure for a medium-sized van).

Let us assume the excavation site is **10 kilometres** away from the starting point (e.g., the office or depot).

Crew Vehicle:

The **crew vehicle** emits **0.2 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.2 kg CO_2/km=4 kg CO_2

So, the **carbon emissions from the crew vehicle** are **4 kg CO_2**.

Total Travel Emissions:

So, the total **travel emissions** for 1 full 8-hour day are **4 kg CO_2**.

As we are calculating per metre and it only takes 0.3 hrs to excavate 1m length then this is reduced to approximately 87.5%

So total travel emissions per 1m of excavation is 4 kg CO_2 *12.5% = **0.5 kg CO_2.**

Step 3: Reinstatement Materials (for Surface Restoration)

For **concrete/asphalt**, restoring the surface will involve **backfilling** to **the surface** using stone prior to the top reinstatement.

Reinstatement (in Tarmac/Concrete)

The **reinstatement emissions for 1 metre in tarmac/concrete**:

4.02 kg CO_2 per meter

For **0.3 metre of reinstatement**, we multiply by 0.3:

4.02 kg CO_2×0.3 =1.206 kg CO_2

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)

Activity	Manual (Hand Tools)
Transport of Imported Backfill	8.0 kg CO_2
Imported Backfill compaction (granular)	3.5 kg CO_2
Hand Tools / Light Machinery compaction	1.0 kg CO_2

Materials: Typically, the **carbon emissions** from the **backfilling materials with imported granular backfill** can be estimated around **3.5 kg CO_2**. This includes **manual labour** for backfilling and compacting the surface.

Transportation of imported backfill material and removal of old backfill can be estimated at **8 kg CO_2**.

For a trench 1m x 1m x 0.3m

15.52 **kg CO_2** x 0.3 = 4.656

So, **carbon emissions from reinstatement materials** are **4.656 kg CO_2**.

Step 4: Pipe Transport Emissions

The 20mm – 50mm pipe will be carried in the team vehicle so no transport for pipe is required

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Total Carbon Emissions for Concrete Excavation

- Carbon from excavation (manual labour):
  - Labour: 0.3 kg CO_2
- Carbon from travel to and from the excavation site:
  - Travel emissions: 0.5 kg CO_2
- Carbon from reinstatement materials (restoring the surface):
  - Reinstatement materials: 4.656 kg CO_2

Total Carbon Emissions: 0.3 kg CO_2+ 0.5 kg CO_2 + 4.656 kg CO_2=**5.256 kg CO_2**

Final Answer:

The total carbon **used or emitted** for **excavating, traveling to and from the site, and reinstating the surface** (manual labour and materials) for a stop tap renewal / service pipe repair in a **concrete/asphalt surface** is approximately:

5.256 kg CO_2

---

13. Renew 1m of 20mm – 50mm service pipe with excavator Soil surface

To calculate the total carbon emissions for installing **1 meter of 20mm to 50mm service pipe** in soil, adjusting for the fact that **a 20mm to 50mm pipe is smaller** than a 150mm pipe. This will reduce some emissions, particularly in **pipe transport**.

Key Assumptions for a 20mm – 50mm Pipe:

Excavation Emissions: Excavation is mostly dependent on the **surface type**, and less on the size of the pipe. The excavation carbon emissions will be similar to those of the 150mm pipe.

Reinstatement Emissions: Similarly, the reinstatement emissions will remain the same because they depend on the excavation and surface restoration, not the pipe size.

Pipe Transport Emissions: Since the **20mm – 50mm pipe is smaller**, we can assume its **transport emissions will be zero as it will be carried in the excavation teams vehicle**.

Travel Emissions: Travel emissions will remain the same, as they depend on the **distance to the site** and **vehicle use**, not the pipe size.

Step 1: Excavation (in soil)

Excavator Efficiency:

A typical **excavator** can move approximately **2m^3 of material per hour** on average, depending on the surface type, material hardness, and operator skill.

For **0.3 x 1 x1** of excavation:

2m^3/hour x 0.3m^3= 0.15hours

So, the excavator will likely take about **.15 hours** to excavate a **1m** trench.

Fuel Consumption and Carbon Emissions:

A **medium-sized diesel excavator** uses around **20 litres of diesel per hour**.

For **0.15 hours** of excavation:

20 litres/hour×0.15 hours=3

3 liters×2.68kg CO_2/litres=8.04kg CO_2

So, the **carbon emissions from the excavator** for **0.15 hours** of digging are approximately **8.04 kg CO_2**.

Step 2: Reinstatement (in soil)

The reinstatement materials backfilling with imported backfill. So, the emissions from the materials used to restore to just below the surface will be:

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)

For **restoring the surface** after excavation, we will assume that the restoration involves **manual labour** and material is **soil**.

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)	
Soil (reused)	0.5 kg CO_2
Hand Tools / Light Machinery	1.5 kg CO_2
Excavator Fuel for backfilling	7.5 kg CO_2

Reinstatement would generate **9.50 kg CO_2**, which includes **manual labour** for backfilling to the surface.

Reinstatement 9.5 kg CO_2 x.15 = 1.425 kg CO_2

Total carbon in the backfilling is **1.425 kg CO_2**

Step 3: Travel Emissions (10 km Round-Trip)

Next, we need to calculate the emissions from travel to and from the site. Let's assume a typical **van or light vehicle** is used for transportation.

Assume a typical vehicle emits about **0.2 kg CO_2 per kilometre** (this is a typical figure for a medium-sized van).

Let us assume the excavation site is **10 kilometres** away from the starting point (e.g., the office or depot).

Excavator Transport:

Excavator emits **0.5 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.5 kg CO_2/km=10 kg CO_2

C**arbon emissions from the excavator** are **10 kg CO_2**. per day

10 kg CO_2.

Crew Vehicle:

The **crew vehicle** emits **0.2 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.2 kg CO_2/km=4 kg CO_2

So, the **carbon emissions from the crew vehicle** are **4 kg CO_2**.

Total Travel Emissions:

10 kg CO_2+4 kg CO_2=14 kg CO_2

So, the total **travel emissions** for 1 full 8-hour day are **14 kg CO_2**.

As we are calculating per metre and it only takes 0.5 hrs to excavate 1m length then this is reduced to approximately 87.5%

So total travel emissions per 1m of excavation is 14 kg CO_2 *12.5% = **1.75 kg CO_2.**

Step 4: Pipe Transport Emissions

The 20mm – 50mm pipe will be carried in the team vehicle so no transport for pipe is required

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Total Carbon Emissions for Installing 1 Meter of 20mm – 50mm Service Pipe in soil

- Carbon from Excavation (in tarmac): 8.04 kg CO_2 (excavation for 1 metre)
- Carbon from Reinstatement (in tarmac): 1.425 kg CO_2 (reinstatement for 1 metre)
- Carbon from Travel: 1.75 kg CO_2 (travel emissions)
- Carbon from Pipe Transport: 0 kg CO_2 (pipe transport for 1 meters)

Total Carbon Emissions: 8.04 kg CO_2+ 1.425 kg CO_2+1.75 kg CO_2 =**11.215 kg CO_2**

Final Answer:

The total carbon **used or emitted** for **installing 1 meter of 20mm service pipe** in a **tarmac road**, including **excavation**, **reinstatement**, **travel**, and **pipe transport**, is approximately:

11.215 kg CO_2

---

14. Renew 1m of 20mm – 50mm service pipe with excavator Stone surface

To calculate the total carbon emissions for installing **1 meter of 20mm to 50mm service pipe** in a stone, adjusting for the fact that **a 20mm to 50mm pipe is smaller** than a 150mm pipe. This will reduce some emissions, particularly in **pipe transport**.

Key Assumptions for a 20mm – 50mm Pipe:

Excavation Emissions: Excavation is mostly dependent on the **surface type**, and less on the size of the pipe. The excavation carbon emissions will be similar to those of the 150mm pipe.

Reinstatement Emissions: Similarly, the reinstatement emissions will remain the same because they depend on the excavation and surface restoration, not the pipe size.

Pipe Transport Emissions: Since the **20mm – 50mm pipe is smaller**, we can assume its **transport emissions will be zero as it will be carried in the excavation teams vehicle**.

Travel Emissions: Travel emissions will remain the same, as they depend on the **distance to the site** and **vehicle use**, not the pipe size.

Step 1: Excavation (in stone)

Excavator Efficiency:

A typical **excavator** can move approximately **1m^3 of material per hour** on average, depending on the surface type, material hardness, and operator skill.

For **0.3 x 1 x1** of excavation:

1m^3/hour x 0.3m^3= 0.3hours

So, the excavator will likely take about **.3 hours** to excavate a **1m** trench.

Fuel Consumption and Carbon Emissions:

A **medium-sized diesel excavator** uses around **20 litres of diesel per hour**.

For **0.3 hours** of excavation:

20 litres/hour×0.3 hours=6.6

6.6 liters×2.68kg CO_2/litres=17.68kg CO_2

So, the **carbon emissions from the excavator** for **0.3 hours** of digging are approximately **17.68 kg CO_2**.

Step 2: Reinstatement (in stone)

The reinstatement materials backfilling with imported backfill. So, the emissions from the materials used to restore to just below the surface will be:

For **restoring the surface** after excavation, we will assume that the restoration involves **manual labour** and material is **stone**.

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)

Soil/Stone (reused)	0.5 kg CO_2
Hand Tools / Light Machinery	1.5 kg CO_2
Excavator Fuel for backfilling	7.5 kg CO_2

Materials: Typically, the **carbon emissions** from the **backfilling materials** using existing excavated material with no imported materials can be estimated around **2.0 kg CO_2**. This includes **manual labour** for backfilling and compacting the surface.

However, this will require stone compacted backfill which increases the reinstatement carbon impact by an extra 50% per 1m^3 so this is estimated to be 3.0 **kg CO_2**

Excavator for backfilling is **7.5 kg CO_2.**

Reinstatement is **3 kg CO_2** + **7.5 kg CO_2** = 10.5 **kg CO_2**

Total 10.5 **kg CO_2 x 0.3 = 3.15 kg CO_2**

Step 3: Travel Emissions (10 km Round-Trip)

Next, we need to calculate the emissions from travel to and from the site. Let's assume a typical **van or light vehicle** is used for transportation.

Assume a typical vehicle emits about **0.2 kg CO_2 per kilometre** (this is a typical figure for a medium-sized van).

Let us assume the excavation site is **10 kilometres** away from the starting point (e.g., the office or depot).

Excavator Transport:

Excavator emits **0.5 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.5 kg CO_2/km=10 kg CO_2

C**arbon emissions from the excavator** are **10 kg CO_2**. per day

10 kg CO_2.

Crew Vehicle:

The **crew vehicle** emits **0.2 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.2 kg CO_2/km=4 kg CO_2

So, the **carbon emissions from the crew vehicle** are **4 kg CO_2.**

Total Travel Emissions:

10 kg CO_2+4 kg CO_2=14 kg CO_2

So, the total **travel emissions** for 1 full 8-hour day are **14 kg CO_2.**

As we are calculating per metre and it only takes 0.5 hrs to excavate 1m length then this is reduced to approximately 87.5%

So total travel emissions per 1m of excavation is 14 kg CO_2 *12.5% = **1.75 kg CO_2.**

Step 4: Pipe Transport Emissions

The 20mm pipe will be carried in the team vehicle so no transport for pipe is required

---

Total Carbon Emissions for Installing 1 Meter of 20mm Service Pipe in stone

Now, let's sum everything up:

- Carbon from Excavation (in tarmac): 17.68 kg CO_2 (excavation for 1 meters)
- Carbon from Reinstatement (in tarmac): 3.15 kg CO_2 (reinstatement for 1 meters)
- Carbon from Travel: 1.75 kg CO_2 (travel emissions)
- Carbon from Pipe Transport: 0 kg CO_2 (pipe transport for 1 meters)

Total Carbon Emissions: 17.68 kg CO_2+3.15 kg CO_2+1.75 kg CO_2 =**22.58 kg CO_2**

Final Answer:

The total carbon **used or emitted** for **installing 1 meter of 20mm service pipe** in a **stone surface**, including **excavation**, **reinstatement**, **travel**, and **pipe transport**, is approximately:

22.58kg CO_2

---

15. Renew 1m of 20mm – 50mm service pipe with excavator concrete / tarmac surface

To calculate the total carbon emissions for installing **1 meter of 20mm to 50mm service pipe** in a concrete / **tarmac**, adjusting for the fact that **a 20mm to 50mm pipe is smaller** than a 150mm pipe. This will reduce some emissions, particularly in **pipe transport**.

Key Assumptions for a 20mm – 50mm Pipe:

Excavation Emissions: Excavation is mostly dependent on the **surface type**, and less on the size of the pipe. The excavation carbon emissions will be similar to those of the 150mm pipe.

Reinstatement Emissions: Similarly, the reinstatement emissions will remain the same because they depend on the excavation and surface restoration, not the pipe size.

Pipe Transport Emissions: Since the **20mm – 50mm pipe is smaller**, we can assume its **transport emissions will be zero as it will be carried in the excavation teams vehicle**.

Travel Emissions: Travel emissions will remain the same, as they depend on the **distance to the site** and **vehicle use**, not the pipe size.

Step 1: Excavation (in Tarmac)

Excavator Efficiency:

A typical **excavator** can move approximately **1m^3 of material per hour** on average, depending on the surface type, material hardness, and operator skill.

For **0.3 x 1 x1** of excavation:

1m^3/hour x 0.3m^3= 0.3hours

So, the excavator will likely take about **.3 hours** to excavate a **1m** trench.

Fuel Consumption and Carbon Emissions:

A **medium-sized diesel excavator** uses around **20 litres of diesel per hour**.

For **0.3 hours** of excavation:

20 litres/hour×0.3 hours=6.6

6.6 liters×2.68kg CO_2/litres=17.68kg CO_2

So, the **carbon emissions from the excavator** for **0.3 hours** of digging are approximately **17.68 kg CO_2**.

Step 2: Reinstatement (in Tarmac/Concrete)

The reinstatement materials backfilling with imported backfill. So, the emissions from the materials used to restore to just below the surface will be:

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)

Activity	**With Excavator**
Transport of Imported Backfill	8.0 kg CO_2
Imported Backfill compaction (granular)	3.5 kg CO_2
Excavator Fuel for backfilling	7.5 kg CO_2

Materials: Typically, the **carbon emissions** from the **backfilling materials with imported granular backfill** can be estimated around **3.5 kg CO_2**. This includes **manual labour** for backfilling and compacting the surface.

Transportation of imported backfill material and removal of old backfill can be estimated at **8 kg CO_2**.

Excavator uses **7.5 kg CO_2**.

Reinstatement is **3.5 kg CO_2 + 8 kg CO_2** + **7.5 kg CO_2** = 19 **kg CO_2**

Total 19 **kg CO_2 x 0.3 = 5.7 kg CO_2**

Reinstatement (in Tarmac/Concrete)

The **reinstatement emissions for 1 metre of trench in tarmac/concrete**:

4.02 kg CO_2 per meter

For **0.5metre of reinstatement**, we multiply by 0.3:

4.02 kg CO_2×0.3 =1.2 kg CO_2

Total **reinstatement emissions are 5.7 + 1.2 = 6.9 kg CO_2**

Step 3: Travel Emissions (10 km Round-Trip)

Next, we need to calculate the emissions from travel to and from the site. Let's assume a typical **van or light vehicle** is used for transportation.

Assume a typical vehicle emits about **0.2 kg CO_2 per kilometre** (this is a typical figure for a medium-sized van).

Let us assume the excavation site is **10 kilometres** away from the starting point (e.g., the office or depot).

Excavator Transport:

Excavator emits **0.5 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.5 kg CO_2/km=10 kg CO_2

C**arbon emissions from the excavator** are **10 kg CO_2**. per day

10 kg CO_2.

Crew Vehicle:

The **crew vehicle** emits **0.2 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.2 kg CO_2/km=4 kg CO_2

So, the **carbon emissions from the crew vehicle** are **4 kg CO_2**.

Total Travel Emissions:

10 kg CO_2+4 kg CO_2=14 kg CO_2

So, the total **travel emissions** for 1 full 8-hour day are **14 kg CO_2**.

As we are calculating per metre and it only takes 0.5 hrs to excavate 1m length then this is reduced to approximately 87.5%

So total travel emissions per 1m of excavation is 14 kg CO_2 *12.5% = **1.75 kg CO_2.**

Step 4: Pipe Transport Emissions

The 20mm pipe will be carried in the team vehicle so no transport for pipe is required

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Total Carbon Emissions for Installing 1 Meter of 20mm Service Pipe in Tarmac

Now, let's sum everything up:

- Carbon from Excavation (in tarmac): 17.68 kg CO_2 (excavation for 1 meters)
- Carbon from Reinstatement (in tarmac): 6.9 kg CO_2 (reinstatement for 1 meters)
- Carbon from Travel: 1.75 kg CO_2 (travel emissions)
- Carbon from Pipe Transport: 0 kg CO_2 (pipe transport for 1 meters)

Total Carbon Emissions: 17.68 kg CO_2+6.9 kg CO_2+1.75 kg CO_2 =**26.33 kg CO_2**

Final Answer:

The total carbon **used or emitted** for **installing 1 meter of 20mm service pipe** in a **tarmac road**, including **excavation**, **reinstatement**, **travel**, and **pipe transport**, is approximately:

26.33kg CO_2

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16. Excavate in soil and replace 1m of 75mm – 150mm main pipe by hand 1m x 1m x 0.3m

Let us go over the same process for **soil excavation**. We will calculate the carbon emissions related to:

Excavation (Manual Labour)

Travel to and from the excavation site

Reinstatement materials (for restoring the surface after the repair)

Step 1: Excavation (Manual Labour)

For **soil excavation**, digging will require less effort compared to **asphalt** or **concrete**, as soil is much softer.

Energy Expenditure for Digging Soil:

A person digging through **soil** typically burns around **600 kcal per hour** of physical effort.

For **2 hours** of digging, the total energy burned would be:

600 kcal/hour×2 hours=1,200 kcal600

Convert this to **megajoules (MJ)**:

1,200 kcal×0.00418=5.016 MJ

Convert to **kWh**:

5.016 MJ×0.000278=0.00139 kWh

Carbon emissions from manual labour:

0.00139 kWh×0.1=0.000139 kg CO_2

To excavate a trench 1x1x.3m^3

0.000139 x 0.3 = .0000463

So, **carbon emissions from manual labour** for digging in 0.3m^3soil is **0.0000463 kg CO_2**.

Step 2: Travel to and From the Excavation Site

Next, we need to calculate the emissions from travel to and from the site. Let's assume a typical **van or light vehicle** is used for transportation.

Assume a typical vehicle emits about **0.2 kg CO_2 per kilometre** (this is a typical figure for a medium-sized van).

Let us assume the excavation site is **10 kilometres** away from the starting point (e.g., the office or depot).

Crew Vehicle:

The **crew vehicle** emits **0.2 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.2 kg CO_2/km=4 kg CO_2

So, the **carbon emissions from the crew vehicle** are **4 kg CO_2**.

Total Travel Emissions:

So, the total **travel emissions** for 1 full 8-hour day are **4 kg CO_2**.

As we are calculating per metre and it only takes 0.3 hrs to excavate 1m length then this is reduced to approximately 87.5%

So total travel emissions per 1m of excavation is 4 kg CO_2 *12.5% = **0.5 kg CO_2**.

Step 3: Reinstatement Materials (for Surface Restoration)

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)

Activity	Manual (Hand Tools)
Soil compaction (reused)	0.5 kg CO_2
Hand Tools / Light Machinery compaction	1.0 kg CO_2

or reinstating the surface after the excavation, we'll assume that **soil backfilling** or **restoring the surface** involves **manual labour** and materials like **soil** or **gravel**.

Materials: Typically, the **carbon emissions** from the **backfilling materials** (soil, gravel, etc.) using existing excavated material with no imported materials can be estimated around **1.5 kg CO_2**. This includes **manual labour** for backfilling and compacting the surface.

For a trench of 1m x m1 x 0.3m

1.5 kg CO_2 x 0.3 = 0.5 kg CO_2

So, **carbon emissions from reinstatement materials** are **0.5 kg CO_2**.

Step 4: Pipe Transport Emissions

Pipe Transport Emissions

The emissions for transporting the **75mm - 150mm pipe**:

1 kg CO_2 per meter of pipe transport

For **1 meter of pipe**, the transport emissions are:

1 kg CO_2×1=1 kg CO_2

Total Carbon Emissions for Soil Excavation

Now let us add everything up:

- Carbon from excavation (manual labour):
  - Labour: 0.0000463 kg CO_2
- Carbon from travel to and from the excavation site:
  - Travel emissions: 0.5 kg CO_2
- Carbon from reinstatement materials (restoring the surface):
  - Reinstatement materials: 0.5 kg CO_2
- Carbon from Pipe Transport:
  - 1 kg CO_2 (pipe transport for 1 meter)

Total Carbon Emissions**:** 0.000463 kg CO_2 + 0.5 kg CO_2 + 0.5 kg CO_2 +1 kg CO_2 = 2.000463

Final Answer:

The total carbon **used or emitted** for **excavating, traveling to and from the site, and reinstating the surface** (manual labour and materials) for an installation of 1m of main pipe in **soil excavation** is approximately:

2 kg CO_2

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17. Excavate in stone and install 1m of 75mm – 150mm service pipe by hand 1m x 1m x 0.3m

For a **stone surface** (similar to digging through stone roads, gravel, or rocky ground), the excavation process will require significantly more energy than digging through soil.

Excavation (Manual Labour)

Travel to and from the excavation site

Reinstatement materials (for restoring the surface after the repair)

Step 1: Excavation (Manual Labour)

Since **stone** is a hard material to dig through, the energy expenditure for manual labour will be higher than soil.

Energy Expenditure for Digging Stone:

A person digging through **stone** typically burns about **1,000 kcal per hour** of strenuous physical activity (comparable to the effort required for breaking concrete).

For **2 hours** of digging, the total energy burned would be:

1,000 kcal/hour×2 hours=2,000 kcal

Convert to **megajoules (MJ)**:

2,000 kcal×0.00418=8.36 MJ

Convert to **kWh**:

8.36 MJ×0.000278=0.00232 kWh

Carbon emissions from manual labour:

0.00232 kWh×0.1=0.000232 kg CO_2

Hand Tools / Light Machinery for excavation 1.0 kg CO_2

To excavate a trench 1m x 1m x 0.3m

1.000232 x 0.3 = 0.3 kg CO_2

So, **carbon emissions from manual labour** for digging through stone are **0.3 kg CO_2**.

Step 2: Travel to and From the Excavation Site

Next, we need to calculate the emissions from travel to and from the site. Let's assume a typical **van or light vehicle** is used for transportation.

Assume a typical vehicle emits about **0.2 kg CO_2 per kilometre** (this is a typical figure for a medium-sized van).

Let us assume the excavation site is **10 kilometres** away from the starting point (e.g., the office or depot).

Crew Vehicle:

The **crew vehicle** emits **0.2 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.2 kg CO_2/km=4 kg CO_2

So, the **carbon emissions from the crew vehicle** are **4 kg CO_2**.

Total Travel Emissions:

So, the total **travel emissions** for 1 full 8-hour day are **4 kg CO_2**.

As we are calculating per metre and it only takes 0.3 hrs to excavate 1m length then this is reduced to approximately 87.5%

So total travel emissions per 1m of excavation is 4 kg CO_2 *12.5% = **0.5 kg CO_2.**

Step 3: Reinstatement Materials (for Surface Restoration)

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)

Activity	Manual (Hand Tools)
Soil/Stone compaction (reused)	0.5 kg CO_2
Hand Tools / Light Machinery compaction	1.0 kg CO_2

For **restoring the surface** after digging, we will assume that **backfilling** with materials like gravel or stone is required.

Materials: Typically, the **carbon emissions** from the **backfilling materials** (soil, gravel, etc.) using existing excavated material with no imported materials can be estimated around **1.5 kg CO_2**. This includes **manual labour** for backfilling and compacting the surface.

However, this will require granular compacted backfill which increases the reinstatement carbon impact by an extra 50% per 1m^3

So, **carbon emissions from reinstatement materials** are **2.25 kg CO_2**.

The **carbon emissions from reinstating to the surface** in stone will be around **2.25 kg CO_2**, which includes **manual labour** for compacting to the surface.

To backfill a trench 1m x 1mm x 0.3m

2.25 **kg CO_2**. x 0.3 = 0.675

So, **carbon emissions from reinstatement materials** are **0.675 kg CO_2**.

Step 4: Pipe Transport Emissions

Pipe Transport Emissions

The emissions for transporting the **75mm - 150mm pipe**:

1 kg CO_2 per meter of pipe transport

For **1 meter of pipe**, the transport emissions are:

1 kg CO_2×1=1 kg CO_2

Total Carbon Emissions for Stone Excavation

Now let us calculate the total carbon emissions:

- Carbon from excavation (manual labour):
    - Labour: 0.3 kg CO_2
- Carbon from travel to and from the excavation site:
    - Travel emissions: 0.5 kg CO_2
- Carbon from reinstatement materials (restoring the surface):
    - Reinstatement materials: 0.675 kg CO_2
- Carbon from Pipe Transport:
    - 1 kg CO_2 (pipe transport for 1 meter)

Total Carbon Emissions: 0.3 kg CO_2+ 0.5 kg CO_2+ 0.675 kg CO_2 + 1 kg CO_2 = 2.475kg CO_2

Final Answer:

The total carbon **used or emitted** for **excavating, traveling to and from the site, and reinstating the surface** (manual labour and materials) for installation of 1m of 75mm – 150mm service pipe in a **stone surface** is approximately:

2.475 kg CO_2

---

18. Excavate in concrete / asphalt and install 1m of 75mm – 150mm service pipe by hand 1m x 1m x 0.3m

For a **concrete / asphalt surface**, the excavation process will be even more energy-intensive than soil due to the **hardness** and **resistance** of concrete/asphalt. Let us go over the carbon emissions for:

Excavation (Manual Labour)

Travel to and from the excavation site

Reinstatement materials (for restoring the surface after the repair)

Step 1: Excavation (Manual Labour)

Digging through **concrete/asphalt** will require a lot of effort, especially if the surface is thick and reinforced. A person typically uses a **sledgehammer**, **pickaxe**, or similar tools, which are much more strenuous than tools used for digging through softer materials like soil.

Energy Expenditure for Digging Concrete/Asphalt:

A person digging through **concrete/asphalt** typically burns around **1,200 kcal per hour** due to the intensive physical work.

For **2 hours** of digging, the total energy burned would be:

1,200 kcal/hour×2 hours=2,400 kcal

Convert this to **megajoules (MJ)**:

2,400 kcal×0.00418=10.032 MJ

Convert to **kWh**:

10.032 MJ×0.000278=0.00279 kWh

Carbon emissions from manual labour:

0.00279 kWh×0.1=0.000279 kg CO_2

Hand Tools / Light Machinery excavation 1.0 kg CO_2

For a trench of 1m x 1m x 0.3m

1.000279 kg CO_2 x 0.3 = 0.3 kg CO_2

So, **carbon emissions from manual labour** for digging through concrete/asphalt are **0.3 kg CO_2**.

Step 2: Travel to and From the Excavation Site

Next, we need to calculate the emissions from travel to and from the site. Let's assume a typical **van or light vehicle** is used for transportation.

Assume a typical vehicle emits about **0.2 kg CO_2 per kilometre** (this is a typical figure for a medium-sized van).

Let us assume the excavation site is **10 kilometres** away from the starting point (e.g., the office or depot).

Crew Vehicle:

The **crew vehicle** emits **0.2 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.2 kg CO_2/km=4 kg CO_2

So, the **carbon emissions from the crew vehicle** are **4 kg CO_2**.

Total Travel Emissions:

So, the total **travel emissions** for 1 full 8-hour day are **4 kg CO_2.**

As we are calculating per metre and it only takes 0.3 hrs to excavate 1m length then this is reduced to approximately 87.5%

So total travel emissions per 1m of excavation is 4 kg CO_2 *12.5% **= 0.5 kg CO_2.**

Step 3: Reinstatement Materials (for Surface Restoration)

For **concrete/asphalt**, restoring the surface will involve **backfilling** to **the surface** using stone prior to the top reinstatement.

Reinstatement (in Tarmac/Concrete)

The **reinstatement emissions for 1 metre in tarmac/concrete**:

4.02 kg CO_2 per meter

For **0.3 metre of reinstatement**, we multiply by 0.3:

4.02 kg CO_2×0.3 =1.206 kg CO_2

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)

Activity	Manual (Hand Tools)
Transport of Imported Backfill	8.0 kg CO_2
Imported Backfill compaction (granular)	3.5 kg CO_2
Hand Tools / Light Machinery compaction	1.0 kg CO_2

Materials: Typically, the **carbon emissions** from the **backfilling materials with imported granular backfill** can be estimated around **3.5 kg CO_2**. This includes **manual labour** for backfilling and compacting the surface.

Transportation of imported backfill material and removal of old backfill can be estimated at **8 kg CO_2**.

For a trench 1m x 1m x 0.3m

15.52 **kg CO_2** x 0.3 = 4.656

So, **carbon emissions from reinstatement materials** are **4.656 kg CO_2**.

Step 4: Pipe Transport Emissions

Pipe Transport Emissions

The emissions for transporting the **75mm - 150mm pipe**:

1 kg CO_2 per meter of pipe transport

For **1 meter of pipe**, the transport emissions are:

1 kg CO_2×1=**1 kg CO_2**

Total Carbon Emissions for Concrete Excavation

- Carbon from excavation (manual labour):
    - Labour: o.3 kg CO_2

- Carbon from travel to and from the excavation site:
    - Travel emissions: 0.5 kg CO_2
- Carbon from reinstatement materials (restoring the surface):
    - Reinstatement materials: 4.656 kg CO_2
- Carbon from Pipe Transport:
    - 1 kg CO_2 (pipe transport for 1 meter)

Total Carbon Emissions: 0.3 kg CO_2+ 0.5 kg CO_2 + 4.656 kg CO_2 + 1 kg CO_2 =6.256 kg CO_2

Final Answer:

The total carbon **used or emitted** for **excavating, traveling to and from the site, and reinstating the surface** (manual labour and materials) for a stop tap renewal / service pipe repair in a **concrete/asphalt surface** is approximately:

6.256 kg CO_2

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19. Renew 1m of 75mm – 150mm service pipe with excavator in Soil

To calculate the total carbon emissions for installing **1 meter of 75mm – 150mm main pipe** in soil. This will increase some emissions, particularly in **pipe transport**.

Key Assumptions for a 75mm - 150mm Pipe:

Excavation Emissions: Excavation is mostly dependent on the **surface type**, and less on the size of the pipe. The excavation carbon emissions will be similar to those of the service pipe.

Reinstatement Emissions: Similarly, the reinstatement emissions will remain the same because they depend on the excavation and surface restoration, not the pipe size.

Pipe Transport Emissions: Since the **75mm – 150mm pipe is larger**, we can assume its **transport emissions will be extra as it will be carried in a separate vehicle**.

Travel Emissions: Travel emissions will remain the same, as they depend on the **distance to the site** and **vehicle use**, not the pipe size.

Step 1: Excavation (in soil)

Excavator Efficiency:

A typical **excavator** can move approximately **2m^3 of material per hour** on average, depending on the surface type, material hardness, and operator skill.

For **0.3 x 1 x1** of excavation:

2m^3/hour x 0.3m^3= 0.15hours

So, the excavator will likely take about **.15 hours** to excavate a **1m** trench.

Fuel Consumption and Carbon Emissions:

A **medium-sized diesel excavator** uses around **20 litres of diesel per hour**.

For **0.15 hours** of excavation:

20 litres/hour×0.15 hours=3

3 liters×2.68kg CO_2/litres=8.04kg CO_2

So, the **carbon emissions from the excavator** for **0.15 hours** of digging are approximately **8.04 kg CO_2**.

Step 2: Reinstatement (in soil)

The reinstatement materials backfilling with imported backfill. So, the emissions from the materials used to restore to just below the surface will be:

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)

For **restoring the surface** after excavation, we will assume that the restoration involves **manual labour** and material is **soil**.

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)	
Soil (reused)	0.5 kg CO_2
Hand Tools / Light Machinery	1.5 kg CO_2
Excavator Fuel for backfilling	7.5 kg CO_2

Reinstatement would generate **9.50 kg CO_2**, which includes **manual labour** for backfilling to the surface.

Reinstatement 9.5 kg CO_2 x.15 = 1.425 kg CO_2

Total carbon in the backfilling is **1.425 kg CO_2**

Step 3: Travel Emissions (10 km Round-Trip)

Next, we need to calculate the emissions from travel to and from the site. Let's assume a typical **van or light vehicle** is used for transportation.

Assume a typical vehicle emits about **0.2 kg CO_2 per kilometre** (this is a typical figure for a medium-sized van).

Let us assume the excavation site is **10 kilometres** away from the starting point (e.g., the office or depot).

Excavator Transport:

Excavator emits **0.5 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.5 kg CO_2/km=10 kg CO_2

C**arbon emissions from the excavator** are **10 kg CO_2**. per day

10 kg CO_2.

Crew Vehicle:

The **crew vehicle** emits **0.2 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.2 kg CO_2/km=4 kg CO_2

So, the **carbon emissions from the crew vehicle** are **4 kg CO_2**.

Total Travel Emissions:

10 kg CO_2+4 kg CO_2=14 kg CO_2

So, the total **travel emissions** for 1 full 8-hour day are **14 kg CO_2**.

As we are calculating per metre and it only takes 0.5 hrs to excavate 1m length then this is reduced to approximately 87.5%

So total travel emissions per 1m of excavation is 14 kg CO_2 *12.5% = **1.75 kg CO_2**.

Step 4: Pipe Transport Emissions

Pipe Transport Emissions

The emissions for transporting the **75mm - 150mm pipe**:

1 kg CO_2 per meter of pipe transport

For **1 meter of pipe**, the transport emissions are:

1 kg CO_2×1=**1 kg CO_2**

Total Carbon Emissions for Installing 1 Meter of 75mm – 150mm main Pipe in soil

- Carbon from Excavation (in soil): 8.04 kg CO_2 (excavation for 1 meters)
- Carbon from Reinstatement (in soil): 1.425 kg CO_2 (reinstatement for 1 meter)
- Carbon from Travel: 1.75 kg CO_2 (travel emissions)
- 4Carbon from Pipe Transport: 1 kg CO_2 (pipe transport for 1 meter)

Total Carbon Emissions: 8.04 kg CO_2+ 1.425 kg CO_2+1.75 kg CO_2 +1 kg CO_2 =12.215 kg CO_2

Final Answer:

The total carbon **used or emitted** for **installing 1 meter of 75mm – 150mm main pipe** in soil, including **excavation**, **reinstatement**, **travel**, and **pipe transport**, is approximately:

12.215 kg CO_2

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20. Renew 1m of 75mm – 150mm main pipe with excavator Stone surface

To calculate the total carbon emissions for installing **1 meter of 75mm – 150mm main pipe** in soil. This will increase some emissions, particularly in **pipe transport**.

Key Assumptions for a 75mm - 150mm Pipe:

Excavation Emissions: Excavation is mostly dependent on the **surface type**, and less on the size of the pipe. The excavation carbon emissions will be similar to those of the service pipe.

Reinstatement Emissions: Similarly, the reinstatement emissions will remain the same because they depend on the excavation and surface restoration, not the pipe size.

Pipe Transport Emissions: Since the **75mm – 150mm pipe is larger**, we can assume its **transport emissions will be extra as it will be carried in a separate vehicle**.

Travel Emissions: Travel emissions will remain the same, as they depend on the **distance to the site** and **vehicle use**, not the pipe size.

Step 1: Excavation (in stone)

Excavator Efficiency:

A typical **excavator** can move approximately **1m^3 of material per hour** on average, depending on the surface type, material hardness, and operator skill.

For **0.3 x 1 x1** of excavation:

1m^3/hour x 0.3m^3= 0.3hours

So, the excavator will likely take about **.3 hours** to excavate a **1m** trench.

Fuel Consumption and Carbon Emissions:

A **medium-sized diesel excavator** uses around **20 litres of diesel per hour**.

For **0.3 hours** of excavation:

20 litres/hour×0.3 hours=6.6

6.6 liters×2.68kg CO_2/litres=17.68kg CO_2

So, the **carbon emissions from the excavator** for **0.3 hours** of digging are approximately **17.68 kg CO_2**.

Step 2: Reinstatement (in stone)

The reinstatement materials backfilling with imported backfill. So, the emissions from the materials used to restore to just below the surface will be:

For **restoring the surface** after excavation, we will assume that the restoration involves **manual labour** and material is **stone**.

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)	
Soil/Stone (reused)	0.5 kg CO_2
Hand Tools / Light Machinery	1.5 kg CO_2
Excavator Fuel for backfilling	7.5 kg CO_2

Materials: Typically, the **carbon emissions** from the **backfilling materials** using existing excavated material with no imported materials can be estimated around **2.0 kg CO_2**. This includes **manual labour** for backfilling and compacting the surface.

However, this will require stone compacted backfill which increases the reinstatement carbon impact by an extra 50% per 1m^3 so this is estimated to be 3.0 **kg CO_2**

Excavator for backfilling is **7.5 kg CO_2.**

Reinstatement is **3 kg CO_2** + **7.5 kg CO_2** = **10.5 kg CO_2**

Total 10.5 **kg CO_2 x 0.3 = 3.15 kg CO_2**

Step 3: Travel Emissions (10 km Round-Trip)

Next, we need to calculate the emissions from travel to and from the site. Let's assume a typical **van or light vehicle** is used for transportation.

Assume a typical vehicle emits about **0.2 kg CO_2 per kilometre** (this is a typical figure for a medium-sized van).

Let us assume the excavation site is **10 kilometres** away from the starting point (e.g., the office or depot).

Excavator Transport:

Excavator emits **0.5 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.5 kg CO_2/km=10 kg CO_2

C**arbon emissions from the excavator** are **10 kg CO_2**. per day

10 kg CO_2.

Crew Vehicle:

The **crew vehicle** emits **0.2 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.2 kg CO_2/km=4 kg CO_2

So, the **carbon emissions from the crew vehicle** are **4 kg CO_2.**

Total Travel Emissions:

10 kg CO_2+4 kg CO_2=14 kg CO_2

So, the total **travel emissions** for 1 full 8-hour day are **14 kg CO_2.**

As we are calculating per metre and it only takes 0.5 hrs to excavate 1m length then this is reduced to approximately 87.5%

So total travel emissions per 1m of excavation is 14 kg CO_2 *12.5% = **1.75 kg CO_2.**

Step 4: Pipe Transport Emissions

The emissions for transporting the **75mm - 150mm pipe**:

1 kg CO_2 per meter of pipe transport

For **1 meter of pipe**, the transport emissions are:

1 kg CO_2×1=1 kg CO_2

Total Carbon Emissions for Installing 1 Meter of 20mm Service Pipe in stone

Now, let's sum everything up:

- Carbon from Excavation (in stone): 17.68 kg CO_2 (excavation for 1 meter)
- Carbon from Reinstatement (in stone): 3.15 kg CO_2 (reinstatement for 1 meter)
- Carbon from Travel: 1.75 kg CO_2 (travel emissions)
- Carbon from Pipe Transport**:** 1 kg CO_2 (pipe transport for 1 meters)

Total Carbon Emissions: 17.68 kg CO_2+3.15 kg CO_2+1.75 kg CO_2 + 1 kg CO_2 =23.58 kg CO_2

Final Answer:

The total carbon **used or emitted** for **installing 1 meter of 20mm service pipe** in a **stone**, including **excavation**, **reinstatement**, **travel**, and **pipe transport**, is approximately:

23.58kg CO_2

21. Renew 1m of 75mm – 150mm mains pipe with excavator concrete / tarmac surface

To calculate the total carbon emissions for installing **1 meter of 75mm – 150mm main pipe** in a concrete / **tarmac**. This will increase some emissions, particularly in **pipe transport**.

Key Assumptions for a 75mm - 150mm Pipe:

Excavation Emissions: Excavation is mostly dependent on the **surface type**, and less on the size of the pipe. The excavation carbon emissions will be similar to those of the service pipe.

Reinstatement Emissions: Similarly, the reinstatement emissions will remain the same because they depend on the excavation and surface restoration, not the pipe size.

Pipe Transport Emissions: Since the **75mm – 150mm pipe is larger**, we can assume its **transport emissions will be extra as it will be carried in a separate vehicle**.

Travel Emissions: Travel emissions will remain the same, as they depend on the **distance to the site** and **vehicle use**, not the pipe size.

Step 1: Excavation (in Tarmac)

Excavator Efficiency:

A typical **excavator** can move approximately **1m^3 of material per hour** on average, depending on the surface type, material hardness, and operator skill.

For **0.3 x 1 x1** of excavation:

1m^3/hour x 0.3m^3= 0.3hours

So, the excavator will likely take about **.3 hours** to excavate a **1m** trench.

Fuel Consumption and Carbon Emissions:

A **medium-sized diesel excavator** uses around **20 litres of diesel per hour**.

For **0.3 hours** of excavation:

20 litres/hour×0.3 hours=6.6

6.6 liters×2.68kg CO_2/litres=17.68kg CO_2

So, the **carbon emissions from the excavator** for **0.3 hours** of digging are approximately **17.68 kg CO_2**.

Step 2: Reinstatement (in Tarmac/Concrete)

The reinstatement materials backfilling with imported backfill. So, the emissions from the materials used to restore to just below the surface will be:

Carbon Emissions Table (kg CO_2 per $1m^3$ backfill only)

Activity	With Excavator
Transport of Imported Backfill	8.0 kg CO_2
Imported Backfill compaction (granular)	3.5 kg CO_2
Excavator Fuel for backfilling	7.5 kg CO_2

Materials: Typically, the **carbon emissions** from the **backfilling materials with imported granular backfill** can be estimated around **3.5 kg CO_2**. This includes **manual labour** for backfilling and compacting the surface.

Transportation of imported backfill material and removal of old backfill can be estimated at **8 kg CO_2**.

Excavator uses **7.5 kg CO_2**.

Reinstatement is **3.5 kg CO_2 + 8 kg CO_2** + **7.5 kg CO_2** = 19 **kg CO_2**

Total 19 **kg CO_2 x 0.5 = 5.7 kg CO_2**

Reinstatement (in Tarmac/Concrete)

The **reinstatement emissions for 1 metre of trench in tarmac/concrete**:

4.02 kg CO_2 per meter

For **0.5metre of reinstatement**, we multiply by 0.3:

4.02 kg CO_2×0.3 =1.2 kg CO_2

Total **reinstatement emissions are 5.7 + 1.2 = 6.9 kg CO_2**

Step 3: Travel Emissions (10 km Round-Trip)

Next, we need to calculate the emissions from travel to and from the site. Let's assume a typical **van or light vehicle** is used for transportation.

Assume a typical vehicle emits about **0.2 kg CO_2 per kilometre** (this is a typical figure for a medium-sized van).

Let us assume the excavation site is **10 kilometres** away from the starting point (e.g., the office or depot).

Excavator Transport:

Excavator emits **0.5 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.5 kg CO_2/km=10 kg CO_2

C**arbon emissions from the excavator** are **10 kg CO_2**. per day

10 kg CO_2.

Crew Vehicle:

The **crew vehicle** emits **0.2 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.2 kg CO_2/km=4 kg CO_2

So, the **carbon emissions from the crew vehicle** are **4 kg CO_2**.

Total Travel Emissions:

10 kg CO_2+4 kg CO_2=14 kg CO_2

So, the total **travel emissions** for 1 full 8-hour day are **14 kg CO_2.**

As we are calculating per metre and it only takes 0.5 hrs to excavate 1m length then this is reduced to approximately 87.5%

So total travel emissions per 1m of excavation is 14 kg CO_2 *12.5% = **1.75 kg CO_2**.

Step 4: Pipe Transport Emissions

The emissions for transporting the **75mm - 150mm pipe**:

1 kg CO_2 per meter of pipe transport

For **1 meter of pipe**, the transport emissions are:

1 kg CO_2×1=1 kg CO_2

Total Carbon Emissions for Installing 1 Meter of 75mm – 150mm main Pipe in Tarmac

Now, let's sum everything up:

- Carbon from Excavation (in tarmac): 17.68 kg CO_2 (excavation for 1 meters)
- Carbon from Reinstatement (in tarmac): 6.9 kg CO_2 (reinstatement for 1 meters)
- Carbon from Travel: 1.75 kg CO_2 (travel emissions)
- Carbon from Pipe Transport: 1 kg CO_2 (pipe transport for 1 meters)

Total Carbon Emissions: 17.68 kg CO_2+6.9 kg CO_2+1.75 kg CO_2 +1 kg CO_2 =27.33 kg CO_2

Final Answer:

The total carbon **used or emitted** for **installing 1 meter of 75mm – 150mm main pipe** in a **tarmac road**, including **excavation**, **reinstatement**, **travel**, and **pipe transport**, is approximately:

27.33kg CO_2

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22. Repair a water main 75mm – 150mm by hand excavation 2m^3 in soil

To calculate the **carbon emissions** for a **hand excavation** of a **burst water main**, we'll need to adjust for the **manual labour** involved in the process. Since this involves **manual digging**, the emissions will primarily come from the **energy burned by the workers** and **travel emissions**.

Step 1: Excavation (Manual Labour)

When a person excavates by hand, they generally burn more **calories** (energy) compared to working with machinery. We need to account for the energy required for the labour and then convert that energy into **carbon emissions**.

Energy Expenditure for Manual Excavation:

A person typically burns around **1,200 kcal per hour** when doing manual excavation work (digging with a shovel, pickaxe, or similar tools). In soil we can consider that the effort is half as much.

For a **burst water main**, let us assume the excavation is **2m^3** excavation (since the hole size will not vary drastically for this type of repair). We will assume it will take **2 hours** to dig by hand.

A person digging through **soil** typically burns around **600 kcal per hour** of physical effort.

For **2 hours** of digging, the total energy burned would be:

600 kcal/hour×2 hours=1,200 kcal600

Convert this to **megajoules (MJ)**:

1,200 kcal×0.00418=5.016 MJ

Convert to **kWh**:

5.016 MJ×0.000278=0.00139 kWh

Carbon emissions from manual labour:

0.00139 kWh×0.1=0.000139 kg CO_2

So, **carbon emissions from manual labour** for digging in soil are **0.000139 kg CO_2**.

Step 2: Water Pumping

Water Pumping

The pumping of water from the burst site also adds **carbon emissions**. A **fuel powered water pump** is typically used for emergency situations like burst water mains.

Water Pump Details:

A **water pump** consumes about **5 litres of fuel per hour** depending on the size and capacity.

For this calculation, we will assume a **small-sized water pump** consumes **3 litres of fuel per hour**.

The pump may need to run for **1 hour** to effectively clear the water from the excavation site.

Fuel Consumption and Carbon Emissions for Water Pump:

Fuel used:

3 litres/hour×1 hours= 3 litres

Carbon emissions:

3 liters×2.68 kg CO_2/litre=8.04 kg

So, **carbon emissions from water pumping** are **8.04 kg CO_2**.

Step 3: Travel to and From the Excavation Site.

Crew Vehicle:

The **crew vehicle** will also travel to and from the site.

Vehicle emissions: **0.2 kg CO_2 per kilometre**

For a **round-trip** of **20 km**:

20 km×0.2 kg CO_2/km=4 kg CO_2

Total Travel Emissions:

4 kg CO_2

So, the total **travel emissions** are **4 kg CO_2**.

Step 4: Reinstatement Materials (for Surface Restoration)

Reinstatement Materials (for Surface Restoration)

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)

Activity	**Manual (Hand Tools)**
Soil/Stone compaction (reused)	0.5 kg CO_2

Activity	Manual (Hand Tools)
Hand Tools / Light Machinery compaction	1.0 kg CO_2

or reinstating the surface after the excavation, we'll assume that **soil backfilling** or **restoring the surface** involves **manual labour** and materials like **soil** or **gravel**.

Materials: Typically, the **carbon emissions** from the **backfilling materials** (soil) using existing excavated material with no imported materials can be estimated around **1.5 kg CO_2 for 1 m^3**. This includes **manual labour** for backfilling and compacting the surface.

So, **carbon emissions from reinstatement materials** for **2 m^3** are **3.0 kg CO_2**.

Total Carbon Emissions for Hand Excavation of 4-inch Burst Water Main

Let us sum up the emissions:

- Carbon from manual excavation (hand digging):
  - Excavation emissions: 0.000139 kg CO_2
- Carbon from water pumping:
  - Water pump emissions: 8.04 kg CO_2
- Carbon from travel to and from the excavation site:
  - Travel emissions: 4 kg CO_2
- Carbon from reinstatement materials:
  - Reinstatement materials: 3.0 kg CO_2

Total Carbon Emissions: 0.000139 kg CO_2+8.04 kg CO_2+4 kg CO_2+3 kg CO_2=15.04 kg CO_2

Final Answer:

The total carbon **used or emitted** for **hand excavation** of a **burst water main**, including **water pumping**, **travel**, and **reinstatement** is approximately:

15.04 kg CO_2

This estimate reflects the emissions associated with **manual labour** for excavation, **water pumping** to clear the site, and **travel** and **surface reinstatement**. The emissions from **manual excavation** are far lower than using mechanical machinery, but water pumping still plays a significant role in carbon output.

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23. Excavate and repair 75mm – 150mm burst main by hand 2m^3 in stone.

To calculate the **carbon emissions** for a **hand excavation** of a **burst water main**, we'll need to adjust for the **manual labour** involved in the process. Since this involves **manual digging**, the emissions will primarily come from the **energy burned by the workers** and **travel emissions**.

Step 1: Excavation (Manual Labour)

Since **stone** is a hard material to dig through, the energy expenditure for manual labour will be higher than soil.

Energy Expenditure for Digging Stone:

A person digging through **stone** typically burns about **1,000 kcal per hour** of strenuous physical activity (comparable to the effort required for breaking concrete).

For **2 hours** of digging, the total energy burned would be:

1,000 kcal/hour×2 hours=2,000 kcal

Convert to **megajoules (MJ)**:

2,000 kcal×0.00418=8.36 MJ

Convert to **kWh**:

8.36 MJ×0.000278=0.00232 kWh

Carbon emissions from manual labour:

0.00232 kWh×0.1=0.000232 kg CO_2

Hand Tools / Light Machinery for excavation 1.0 kg CO_2

So, **carbon emissions from manual labour** for digging through stone are **1.000232 kg CO_2**.

Step 2: Water Pumping

Water Pumping

The pumping of water from the burst site also adds **carbon emissions**. A **fuel powered water pump** is typically used for emergency situations like burst water mains.

Water Pump Details:

A **water pump** consumes about **5 litres of fuel per hour** depending on the size and capacity.

For this calculation, we will assume a **small-sized water pump** consumes **3 litres of fuel per hour**.

The pump may need to run for **1 hour** to effectively clear the water from the excavation site.

Fuel Consumption and Carbon Emissions for Water Pump:

Fuel used:

3 litres/hour×1 hours= 3 litres

Carbon emissions:

3 liters×2.68 kg CO_2/litre=8.04 kg

So, **carbon emissions from water pumping** are **8.04 kg CO_2**.

Step 3: Travel to and From the Excavation Site

The travel emissions will still involve both the **excavator's transport** and the **crew vehicle**.

Crew Vehicle:

The **crew vehicle** emits **0.2 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.2 kg CO_2/km=4 kg CO_2

So, the **carbon emissions from the crew vehicle** are **4 kg CO_2**.

Total Travel Emissions:

So, the total **travel emissions** remain **4 kg CO_2**.

Step 4: Reinstatement Materials (for Surface Restoration)

For **restoring the surface** after excavation, we will assume that the restoration involves **manual labour** and material is **stone**.

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)	
Soil (reused)	0.5 kg CO_2
Hand Tools / Light Machinery for stone	1.5 kg CO_2

Materials: Typically, the **carbon emissions** from the **backfilling materials** using existing excavated material with no imported materials can be estimated around **2.0 kg CO_2**.

The **carbon emissions from reinstating to the surface** in stone for **2 m^3** will be **4.0 kg CO_2**, which includes **manual labour** for compacting to the surface.

So, **carbon emissions from reinstatement materials** are **4.0 kg CO_2**.

Total Carbon Emissions for 2m^3 Excavation by hand

Let's now sum up the emissions:

- Carbon from excavation:
  - Excavation emissions: 1.000232 kg CO_2
- Carbon from travel to and from the excavation site:
  - Travel emissions: 4 kg CO_2
- Carbon from water pump:
  - Travel emissions: 8.04 kg CO_2

- Carbon from reinstatement materials (restoring the surface):
    - Reinstatement materials: 4.0kg CO_2

Total Carbon Emissions: 1.000232 kg CO_2+ 4 kg CO_2 + 8.04 kg CO_2 **+** 4 kg CO_2= **17.04 kg CO_2**

Final Answer:

The total carbon **used or emitted** for **excavating, traveling to and from the site, and reinstating the surface** for a **2m^3 manual excavation** in a **stone surface** is approximately:

17.04 kg CO_2

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24. Excavate and repair 75mm – 150mm burst main by hand 2m^3 in Concrete/Asphalt

This result shows a significant increase in carbon emissions compared to manual labour due to the **excavator's fuel consumption** and the **transportation emissions** for the machinery and crew.

Excavating a larger hole 2x1x1

If we're now considering the excavation of a **2m^3** hole, we need to adjust the calculations to account for the **larger excavation volume**.

Let's go through the breakdown again for a **2m^3 excavation** using hand excavation:

Step 1: Excavation

For a **concrete / asphalt surface**, the excavation process will be even more energy-intensive than soil due to the **hardness** and **resistance** of concrete/asphalt. Let us go over the carbon emissions for:

Excavation (Manual Labour)

Travel to and from the excavation site

Reinstatement materials (for restoring the surface after the repair)

Step 1: Excavation (Manual Labour)

Digging through **concrete/asphalt** will require a lot of effort, especially if the surface is thick and reinforced. A person typically uses a **sledgehammer**, **pickaxe**, or similar tools, which are much more strenuous than tools used for digging through softer materials like soil.

Energy Expenditure for Digging Concrete/Asphalt:

A person digging through **concrete/asphalt** typically burns around **1,200 kcal per hour** due to the intensive physical work.

For **2 hours** of digging, the total energy burned would be:

1,200 kcal/hour×2 hours=2,400 kcal

Convert this to **megajoules (MJ)**:

2,400 kcal×0.00418=10.032 MJ

Convert to **kWh**:

10.032 MJ×0.000278=0.00279 kWh

Carbon emissions from manual labour:

0.00279 kWh×0.1=0.000279 kg CO_2

Hand Tools / Light Machinery excavation 1.0 kg CO_2

So, **carbon emissions from manual labour** for digging through concrete/asphalt are **1.000279 kg CO_2**.

Step 2: Travel to and From the Excavation Site

Crew Vehicle:

The **crew vehicle** emits **0.2 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.2 kg CO_2/km=4 kg CO_2

So, the **carbon emissions from the crew vehicle** are **4 kg CO_2**.

Total Travel Emissions:

4 kg CO_2=4 kg CO_2

So, the total **travel emissions** remain **4 kg CO_2**.

Step 3: Water Pumping

The pumping of water from the burst site also adds **carbon emissions**. A **fuel powered water pump** is typically used for emergency situations like burst water mains.

Water Pump Details:

A **water pump** consumes about **litres of fuel per hour** depending on the size and capacity.

For this calculation, we will assume a **small-sized water pump** consumes **3 litres of fuel per hour**.

The pump may need to run for **1 hour** to effectively clear the water from the excavation site.

Fuel Consumption and Carbon Emissions for Water Pump:

Fuel used:

3 litres/hour×1 hours= 3 litres

Carbon emissions:

3 liters×2.68 kg CO_2/litre=8.04 kg

So, **carbon emissions from water pumping** are **8.04 kg CO_2**.

Step 4: Reinstatement Materials (for Surface Restoration)

Carbon Emissions Table (kg CO_2 per $1m^3$ backfill only)

Activity	Manual (Hand Tools)
Transport of Imported Backfill	8.0 kg CO_2 transport is regardless of m3 delivered
Imported Backfill compaction (granular)	3.5 kg CO_2
Hand Tools / Light Machinery compaction	1.0 kg CO_2

The reinstatement materials backfilling with imported backfill. So, the emissions from the materials used to restore to just below the surface will be:

Reinstatement is **8 kg CO_2 + 3.5 kg CO_2 + 1 kg CO_2** = **12.5 kg CO_2**

Total 12.5 kg CO_2 x 2 = 25 kg CO_2 - 8 kg CO_2 = 18 kg CO_2. Note: Transport of Imported Backfill is done once for $2m^3$ thus the deduction of 8 kg CO_2 to consider a single run.

For **concrete/asphalt**, restoring the surface will involve **backfilling** to **the surface** using stone prior to the top reinstatement.

Reinstatement (in Tarmac/Concrete)

The **reinstatement emissions for 1 metre in tarmac/concrete**:

4.02 kg CO_2 per meter

For **2 metres of reinstatement**, we multiply by 2:

4.02 kg CO_2×2=8.04 kg CO_2

Carbon emissions from reinstatement materials are

8.04 kg CO_2 + 18 kg CO_2 = 26.04 kg CO_2.

Total Carbon Emissions for 2m^3 manual hand Excavation

Let's now sum up the emissions:

- Carbon from excavation (manual excavation):
  - Excavator emissions: 1.000279 kg CO_2
- Carbon from travel to and from the excavation site:
  - Travel emissions: 4 kg CO_2
- Carbon from water pump:
  - Pump emissions: 8.04 kg CO_2
- Carbon from reinstatement materials (restoring the surface):
  - Reinstatement materials: 26.04 kg CO_2

Total Carbon Emissions: 1.000279 kg CO_2+4 kg CO_2+ 8.04 + 26.04 kg CO_2 =**39.08kg CO_2**

kg CO_2

Final Answer:

The total carbon **used or emitted** for **excavating, traveling to and from the site, and reinstating the surface** using manual **excavation** for a **2m^3** excavation in a **concrete/asphalt surface** is approximately:

39.08 kg CO_2

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25. Excavate and repair 75mm – 150mm burst main using mechanical excavator 2m^3 in Soil

This result shows a significant increase in carbon emissions compared to manual labour due to the **excavator's fuel consumption** and the **transportation emissions** for the machinery and crew.

Excavating a larger hole 2x1x1

If we're now considering the excavation of a **2m^3** hole, we need to adjust the calculations to account for the **larger excavation volume**. Given that the **excavator** will be working for a longer period of time, we'll increase the time spent on excavation and adjust the emissions accordingly.

Breakdown for a **2m^3 excavation** using a mechanical excavator:

Step 1: Excavation (Mechanical Excavator)

A **2m^3 excavation** will take longer for the excavator compared to a 1m^3 excavation. We'll estimate the required time based on the volume of material being moved.

Excavator Efficiency:

A typical **excavator** can move approximately in soil **2.0m^3 of material per hour** on average, depending on the surface type, material hardness, and operator skill.

For **2m^3** of excavation:

2.0m^3/hour2m^3=1 hour

So, the excavator will likely take about **1 hours** to excavate a **2m^3** hole.

Fuel Consumption and Carbon Emissions:

As mentioned before, a **medium-sized diesel excavator** uses around **20 litres of diesel per hour**.

For **1 hour** of excavation:

20 litres/hour ×1 hours=20

20 litres × 2.68kg CO_2/litres=53.6kg CO_2

Carbon emissions from the excavator for **2 hours** of digging are **approximately 53.6 kg CO_2**.

Step 2: Travel to and From the Excavation Site

The travel emissions will still involve both the **excavator's transport** and the **crew vehicle**.

Excavator Transport:

Excavator emits **0.5 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.5 kg CO_2/km=10 kg CO_2

C**arbon emissions from the excavator** are **10 kg CO_2**.

Crew Vehicle:

The **crew vehicle** emits **0.2 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.2 kg CO_2/km=4 kg CO_2

So, the **carbon emissions from the crew vehicle** are **4 kg CO_2**.

Total Travel Emissions:

10 kg CO_2+4 kg CO_2=14 kg CO_2

So, the total **travel emissions** remain **14 kg CO_2**.

Step 3: Water Pumping

The pumping of water from the burst site also adds **carbon emissions**. A **fuel powered water pump** is typically used for emergency situations like burst water mains.

Water Pump Details:

A **water pump** consumes about **litres of fuel per hour** depending on the size and capacity.

For this calculation, we will assume a **small-sized water pump** consumes **3 litres of fuel per hour**.

The pump may need to run for **1 hour** to effectively clear the water from the excavation site.

Fuel Consumption and Carbon Emissions for Water Pump:

Fuel used:

3 litres/hour×1 hours= 3 litres

Carbon emissions:

3 liters×2.68 kg CO_2/litre=8.04 kg

So, **carbon emissions from water pumping** are **8.04 kg CO_2**.

Step 4: Reinstatement Materials (for Surface Restoration)

For **restoring the surface** after excavation, we will assume that the restoration involves **manual labour** and material is **soil**.

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)	
Soil/Stone (reused)	0.5 kg CO_2
Hand Tools / Light Machinery	1.5 kg CO_2
Excavator Fuel for backfilling	7.5 kg CO_2

Reinstatement would generate **9.50 kg CO_2**, which includes **manual labour** for backfilling to the surface.

Reinstatement 9.5 kg CO_2 x2 = 19 kg CO_2

Total carbon in the backfilling is **19 kg CO_2** = **19 kg CO_2**

Total Carbon Emissions for 2m^3 Excavation Using an Excavator

Let's now sum up the emissions:

- Carbon from excavation (mechanical excavator):

- Excavator emissions: 53.6 kg CO_2
- Carbon from travel to and from the excavation site:
  - Travel emissions: 14 kg CO_2
- Carbon from water pump:
  - Pump emissions: 8.04 kg CO_2
- Carbon from reinstatement materials (restoring the surface):
  - Reinstatement materials: 19.0 kg CO_2

Total Carbon Emissions: 53.6 kg CO_2+14 kg CO_2+ 8.04 kg CO_2 + 19.0 kg CO_2=94.64 kg CO_2

Final Answer:

The total carbon **used or emitted** for **excavating, traveling to and from the site, and reinstating the surface** using a **mechanical excavator** for a **2m^3** excavation in a **soil surface** is approximately:

94.64 kg CO_2

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26. Excavate and repair 75mm – 150mm burst main using mechanical excavator 2m^3 in Stone.

This result shows a significant increase in carbon emissions compared to manual labour due to the **excavator's fuel consumption** and the **transportation emissions** for the machinery and crew.

Excavating a larger hole 2x1x1

If we're now considering the excavation of a **2m^3** hole, we need to adjust the calculations to account for the **larger excavation volume**. Given that the **excavator** will be working for a longer period of time, we'll increase the time spent on excavation and adjust the emissions accordingly.

Let's go through the breakdown again for a **2m^3 excavation** using a mechanical excavator:

Step 1: Excavation (Mechanical Excavator)

A **2m^3 excavation** will take longer for the excavator compared to a 1m^3 excavation. We'll estimate the required time based on the volume of material being moved.

Excavator Efficiency:

A typical **excavator** can move approximately **1.0m^3 of material per hour** on average, depending on the surface type, material hardness, and operator skill.

For **2m^3** of excavation:

1.0m^3/hour2m^3=2hours

So, the excavator will likely take about **2 hours** to excavate a **2m^3** hole.

Fuel Consumption and Carbon Emissions:

As mentioned before, a **medium-sized diesel excavator** uses around **20 litres of diesel per hour**.

For **2 hours** of excavation:

20 litres/hour×2 hours=40

40 liters×2.68kg CO_2/litres=107.2 kg CO_2

So, the **carbon emissions from the excavator** for **4 hours** of digging are approximately **107.2 kg CO_2**.

Step 2: Travel to and From the Excavation Site

The travel emissions will still involve both the **excavator's transport** and the **crew vehicle**.

Excavator Transport:

Excavator emits **0.5 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.5 kg CO_2/km=10 kg CO_2

C**arbon emissions from the excavator** are **10 kg CO_2**.

Crew Vehicle:

The **crew vehicle** emits **0.2 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.2 kg CO_2/km=4 kg CO_2

So, the **carbon emissions from the crew vehicle** are **4 kg CO_2**.

Total Travel Emissions:

10 kg CO_2+4 kg CO_2=14 kg CO_2

So, the total **travel emissions** remain **14 kg CO_2**.

Step 3: Water Pumping

The pumping of water from the burst site also adds **carbon emissions**. A **fuel powered water pump** is typically used for emergency situations like burst water mains.

Water Pump Details:

A **water pump** consumes about **litres of fuel per hour** depending on the size and capacity.

For this calculation, we will assume a **small-sized water pump** consumes **3 litres of fuel per hour**.

The pump may need to run for **1 hour** to effectively clear the water from the excavation site.

Fuel Consumption and Carbon Emissions for Water Pump:

Fuel used:

3 litres/hour×1 hours= 3 litres

Carbon emissions:

3 liters×2.68 kg CO_2/litre=8.04 kg

So, **carbon emissions from water pumping** are **8.04 kg CO_2**.

Step 4: Reinstatement Materials (for Surface Restoration)

For **restoring the surface** after excavation, we will assume that the restoration involves **manual labour** and material is **stone**.

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)

Soil/Stone (reused)	0.5 kg CO_2
Hand Tools / Light Machinery	1.5 kg CO_2
Excavator Fuel for backfilling	7.5 kg CO_2

Materials: Typically, the **carbon emissions** from the **backfilling materials** using existing excavated material with no imported materials can be estimated around **2.0 kg CO_2**. This includes **manual labour** for backfilling and compacting the surface.

However, this will require stone compacted backfill which increases the reinstatement carbon impact by an extra 50% per 1m^3 so this is estimated to be 3.0 **kg CO_2**

Excavator for backfilling is **7.5 kg CO_2.**

Reinstatement total: **10.5 kg CO_2 x2 = 21 kg CO_2**

Total Carbon Emissions for 2m^3 Excavation Using an Excavator

Let's now sum up the emissions:

- Carbon from excavation (mechanical excavator):
  - Excavator emissions: 107.2 kg CO_2
- Carbon from travel to and from the excavation site:
  - Travel emissions: 14 kg CO_2

- Carbon from water pump:
    - Pumpl emissions: 8.04 kg CO_2
- Carbon from reinstatement materials (restoring the surface):
    - Reinstatement materials: 21 kg CO_2

Total Carbon Emissions: 107.2 kg CO_2+14 kg CO_2+8.04 kg CO_2 **+** 21 kg CO_2= 150.24 kg CO_2

Final Answer:

The total carbon **used or emitted** for **excavating, traveling to and from the site, and reinstating the surface** using a **mechanical excavator** for a **2m^3** excavation in a **stone surface** is approximately:

150.24 kg CO_2

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27. Excavate and repair 75mm – 150mm burst main excavating by mechanical excavator 2m^3 in Concrete/Asphalt.

This result shows a significant increase in carbon emissions compared to manual labour due to the **excavator's fuel consumption** and the **transportation emissions** for the machinery and crew.

Excavating a larger hole 2x1x1

If we're now considering the excavation of a **2m^3** hole, we need to adjust the calculations to account for the **larger excavation volume**. Given that the **excavator** will be working for a longer period of time, we'll increase the time spent on excavation and adjust the emissions accordingly.

Let's go through the breakdown again for a **2m^3 excavation** using a mechanical excavator:

Step 1: Excavation (Mechanical Excavator)

A **2m^3 excavation** will take longer for the excavator compared to a 1m^3 excavation. We'll estimate the required time based on the volume of material being moved.

Excavator Efficiency:

A typical **excavator** can move approximately **1.0m^3 of material per hour** on average, depending on the surface type, material hardness, and operator skill.

For **2m^3** of excavation:

1.0m^3/hour2m^3=2hours

So, the excavator will likely take about **2 hours** to excavate a **2m^3** hole.

Fuel Consumption and Carbon Emissions:

As mentioned before, a **medium-sized diesel excavator** uses around **20 litres of diesel per hour**.

For **2 hours** of excavation:

20 litres/hour×2 hours=40

40 liters×2.68kg CO_2/litres=107.2kg CO_2

So, the **carbon emissions from the excavator** for **4 hours** of digging are approximately **107.2 kg CO_2**.

Step 2: Travel to and From the Excavation Site

The travel emissions will still involve both the **excavator's transport** and the **crew vehicle**.

Excavator Transport:

Excavator emits **0.5 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.5 kg CO_2/km=10 kg CO_2

C**arbon emissions from the excavator** are **10 kg CO_2**.

Crew Vehicle:

The **crew vehicle** emits **0.2 kg CO_2 per kilometre**.

For a **round-trip** of **20 km**:

20 km×0.2 kg CO_2/km=4 kg CO_2

So, the **carbon emissions from the crew vehicle** are **4 kg CO_2**.

Total Travel Emissions:

10 kg CO_2+4 kg CO_2=14 kg CO_2

So, the total **travel emissions** remain **14 kg CO_2**.

Step 3: Water Pumping

The pumping of water from the burst site also adds **carbon emissions**. A **fuel powered water pump** is typically used for emergency situations like burst water mains.

Water Pump Details:

A **water pump** consumes about **litres of fuel per hour** depending on the size and capacity.

For this calculation, we will assume a **small-sized water pump** consumes **3 litres of fuel per hour**.

The pump may need to run for **1 hour** to effectively clear the water from the excavation site.

Fuel Consumption and Carbon Emissions for Water Pump:

Fuel used:

3 litres/hour×1 hours= 3 litres

Carbon emissions:

3 liters×2.68 kg CO_2/litre=8.04 kg

So, **carbon emissions from water pumping** are **8.04 kg CO_2**.

Step 4: Reinstatement Materials (for Surface Restoration)

The reinstatement materials backfilling with imported backfill. So, the emissions from the materials used to restore to just below the surface will be:

Carbon Emissions Table (kg CO_2 per 1m^3 backfill only)

Activity	With Excavator
Transport of Imported Backfill	8.0 kg CO_2 - transport is regardless of m^3 delivered
Imported Backfill compaction (granular)	3.5 kg CO_2
Excavator Fuel for backfilling	7.5 kg CO_2

Reinstatement is **8 kg CO_2** + **3.5 kg CO_2 + 7.5 kg CO_2** = **19 kg CO_2**

Total 19 **kg CO_2 x 2 = 38 kg CO_2 - 8 kg CO_2 = 30 kg CO_2** Note: Transport of Imported Backfill is done once for 2m3 thus the deduction of 8 kg CO2 to consider a single run.

For **concrete/asphalt**, restoring the surface will involve **backfilling** to **the surface** using granular material prior to the top reinstatement.

Reinstatement (in Tarmac/Concrete)

The **reinstatement emissions for 1 metre in tarmac/concrete**:

4.02 kg CO_2 per meter

For **2 metres of reinstatement**, we multiply by 2: 4.02 kg CO_2×2=8.04 kg CO_2

Carbon emissions from reinstatement materials are

8.04 kg CO_2 + 30 kg CO_2 = 38.04 kg CO_2.

Total Carbon Emissions for 2m^3 Excavation Using an Excavator

Let's now sum up the emissions:

- Carbon from excavation (mechanical excavator):
  - Excavator emissions: 107.2 kg CO_2
- Carbon from travel to and from the excavation site:
  - Travel emissions: 14 kg CO_2
- Carbon from water pump:
  - Pump emissions: 8.04 kg CO_2
- Carbon from reinstatement materials (restoring the surface):
  - Reinstatement materials: 38.04 kg CO_2

Total Carbon Emissions: 107.2 kg CO_2+14 kg CO_2+ 8.04 kg CO_2 **+** 38.04 kg CO_2=**167.28 kg CO_2**

Final Answer:

The total carbon **used or emitted** for **excavating, traveling to and from the site, and reinstating the surface** using a **mechanical excavator** for a **2m^3** excavation in a **concrete/asphalt surface** is approximately:

167.28 kg CO_2

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28. Water Meter exchange 15mm to 25mm no excavation required.

Total Carbon Emissions (Excluding Reinstatement)

- Carbon from Manual Excavation (hand digging):
  - Excavation emissions: 0.000279 kg CO_2
- Carbon from Travel to and from site:
  - Travel emissions: 2 kg CO_2 (for a 10 km round-trip)

Updated Total Carbon Emissions: 0.000279 kg CO_2+2 kg CO_2=2.000279 kg CO_2

Final Answer (no reinstatement required):

The total carbon **used or emitted** for **replacing a 20mm water meter**, including **excavation** and **travel**, with a **10 km round-trip** distance and **no reinstatement**, is approximately:

2.00 kg CO_2

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29. Water meter Reading

Total Carbon Emissions

- **Carbon from Manual work:**
  - **Excavation emissions**: **0.000279 kg CO_2**

- **Carbon from Travel to and from site:**
    - **Travel emissions**: **2 kg CO_2** (for a **10 km round-trip**)

Updated Total Carbon Emissions: 0.000279 kg CO_2+7 kg CO_2=2.000279 kg CO_2

Final Answer

100 water meters read per day

2.000279 / 100 = 0.02 kg CO_2 per meter read

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30. Leak detection listening per fitting

Total Carbon Emissions

- Carbon from Manual work:
    - Excavation emissions: 0.000279 kg CO_2
- Carbon from Travel to and from Site:
    - Travel emissions: 2 kg CO_2 (for a 10 km round-trip)

Updated Total Carbon Emissions: 0.000279 kg CO_2+2 kg CO_2=2.000279 kg CO_2

Final Answer

100 fittings listened on per day= 2.000279 / 100 = 0.02 kg CO_2 per fitting listened on