# Report for Lake Macquarie City Council: Use of recycled materials in roads.

11th October 2021.

This project was supported by

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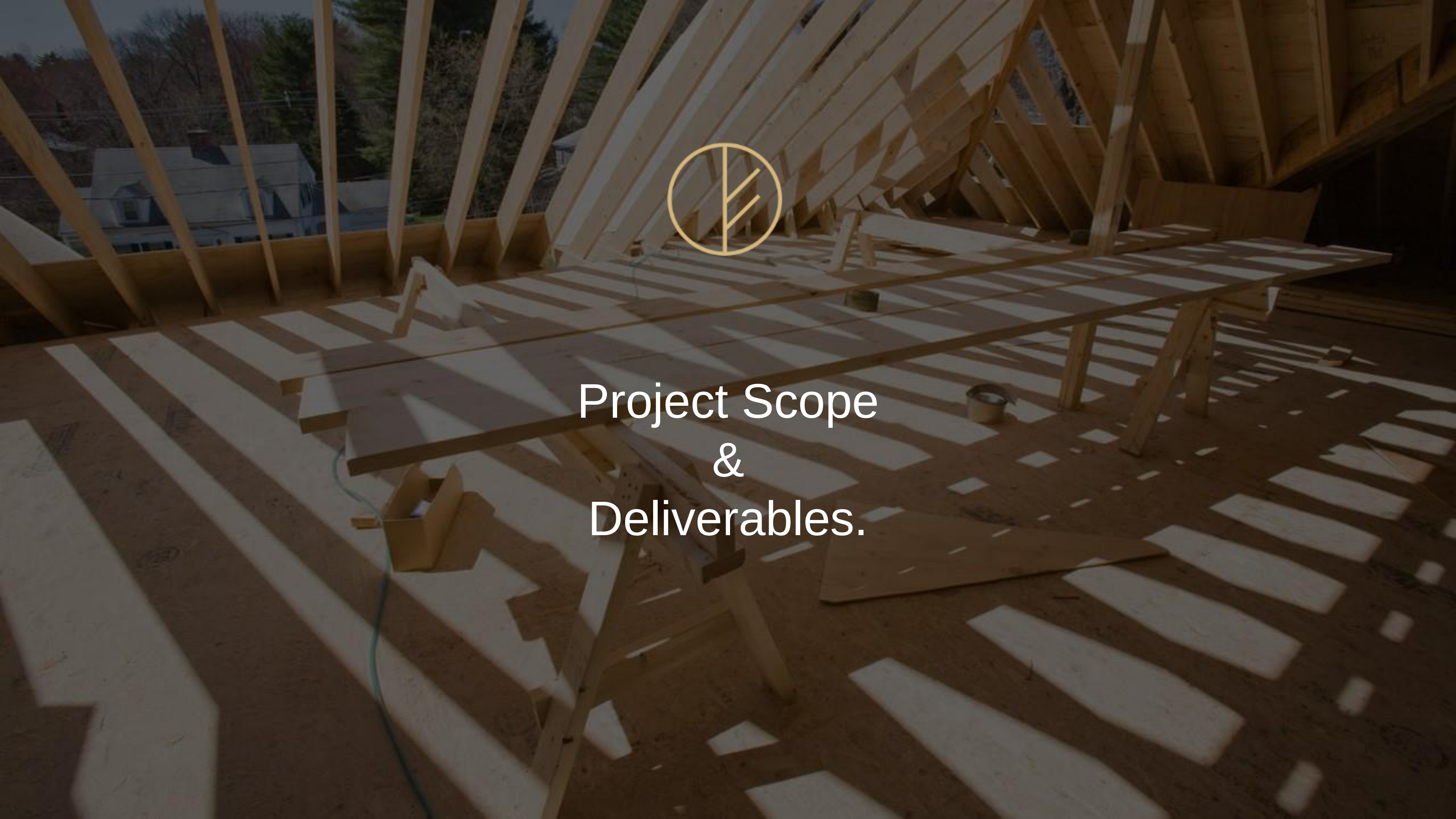


# Project Scope & Deliverables.

# Project scope and deliverables

**The primary aim of this project is to provide Lake Macquarie City Council (LMCC) with an Excel based tool to evaluate and compare the environmental impacts / benefits of using recycled materials in roads.**

The tool offers LMCC the flexibility to input / modify key parameters (see below) and evaluate their influence on the environmental footprint and emissions abatement cost of the road:

- Life span.
- Road structure e.g., layer thicknesses for wearing, base and subbase courses.
- Recycled material content – i.e., ability to vary the amount of recycled materials
- Renewable vs grid energy for processing of recycle materials.
- Transport/collection distance for recycled materials.
- Quantities of key components in the road structure e.g. concrete, aggregates, sand and asphalt.
- Costs for purchasing materials, carbon offsets, and transportation.

***Note: In line with the ISO guidance, Edge recommends that the report and the tool be third-party verified before circulating outside of LMCC and other partner organisations.***

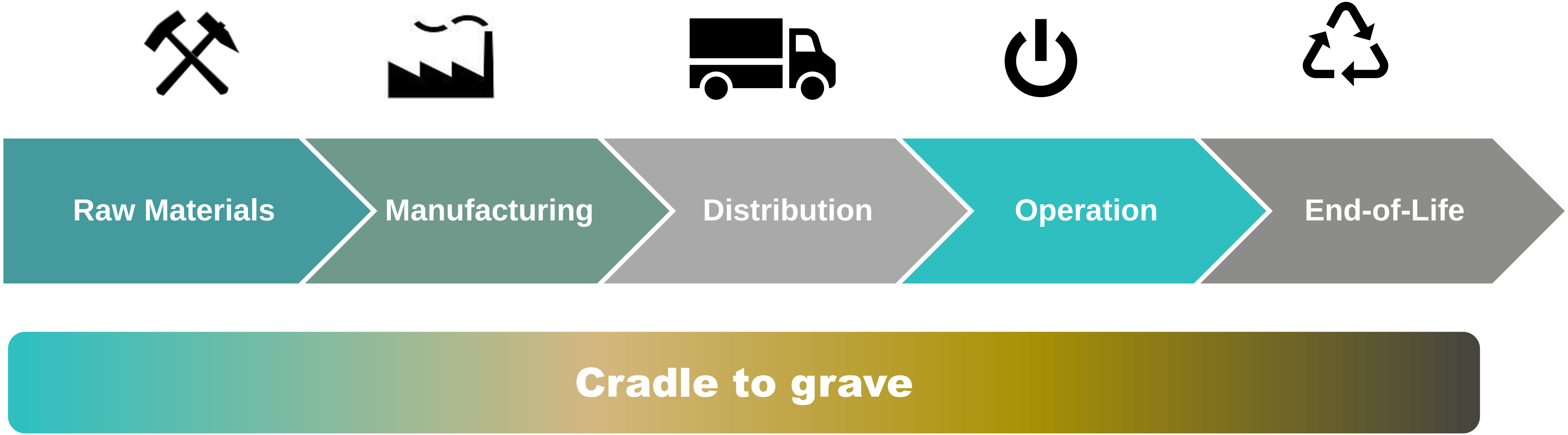
# Project approach
# &
# Life Cycle Assessment (LCA) methodology

# Project approach

| | | |
|---|---|---|
| 1 | LCA scope | Cradle to grave |
| 2 | Baseline | LMCC |
| 3 | Replacement materials | 6 materials |
| 4 | Life cycle inventory | Edge \| LMCC |
| 5 | Impact assessment and analysis | Edge |
| 6 | Reporting | Edge |

# LCA methodology: Scope and Functional unit

Scope of the LCA is cradle to grave. The life cycle stages included in the LCA are depicted below.



Raw Materials

Manufacturing

Distribution

Operation

End-of-Life

**Cradle to grave**

# LCA methodology: Database and impact indicators

- The LCA is aligned to relevant international standards i.e., ISO 14040/ 44/ 67.
- Simapro v9.1.1.1. software, AusLCI v1.31 and Ecoinvent v3.6 databases, and EPDs have been utilised for developing the LCA underlying the Excel based tool.
- The following environmental impact indicators have been analysed in this LCA using the ReCiPe 2016 method:

| Environmental Impact Indicator | Unit |
|---|---|
| Global warming potential (GWP) | kg $CO_2$ eq. |
| Water use | $m^3$ of $H_2O$ |
| Terrestrial ecotoxicity | kg 1,4 – dichlorobenzene (DCB) |
| Freshwater ecotoxicity | |
| Marine ecotoxicity | |
| Human carcinogenic toxicity | |

*There is a high level of uncertainty involved in the factors (background data) for ecotoxicity indicators. The assessment of environmental fate of the materials using these indicators requires additional data and research. Edge recommends that further research be undertaken/ commissioned on this topic before publishing the results form these indicators or using them for decision making.*

# LCA methodology: Functional unit (FU)

Functional unit: 1km of two-lane paved road, evaluated over its Reference Service Life

| | | | |
|---|---|---|---|
| **Product Stage** | Raw Material Supply | A1 | ✓ |
| | Transport | A2 | ✓ |
| | Manufacturing | A3 | ✓ |
| **Const-ruction Stage** | Transport | A4 | ✓ |
| | Construction / installation process | A5 | ✓ |
| **Use Stage** | Use | B1 | ✓ |
| | Maintenance incl. transport | B2 | ✓ |
| | Repair incl. transport | B3 | ✓ |
| | Replacement incl. transport | B4 | ✓ |
| | Refurbishment incl. transport | B5 | ✗ |
| | Operational Energy Use | B6 | ✗ |
| | Operational Water Use | B7 | ✗ |
| **End of Life Stage** | De-construction & demolition | C1 | ✓ |
| | Transport | C2 | ✓ |
| | Re-use recycling | C3 | ✓ |
| | Final Disposal | C4 | ✓ |
| **Benefits & loads for the next product system** | Reuse, Recovery Recycling potential | D | ✓ |

# LCA methodology: Recycled material inclusions

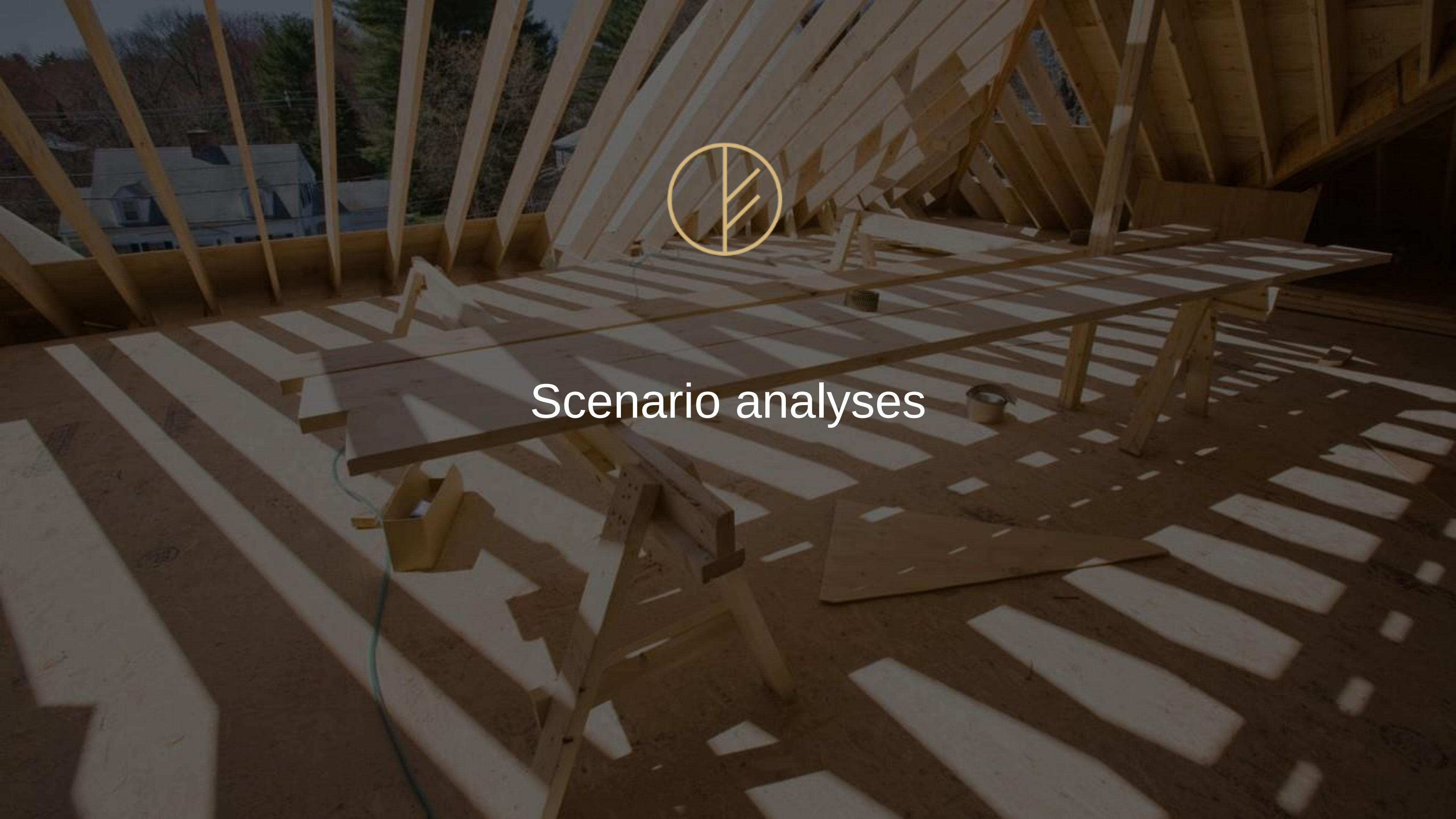
1. Glass
2. Plastics
3. Toner
4. Fly ash
5. Recycled concrete
6. Crushed brick
7. Reclaimed Asphalt Pavement (RAP)
8. Recycled tile
9. Waste tyre

Most of these materials will replace different types of (virgin) aggregates used in road construction.

# LCA methodology - Key assumptions for baseline scenario

| No. | Item | Response |
|---|---|---|
| 1 | Life span of the road | 40 years |
| 2 | Life span of the asphalt layer/ re-surfacing schedule | 15 years |
| 3 | Functional unit | 1km of paved road, evaluated over its Reference Service Life. |
| 4 | % RAP in asphalt | 30% |
| 5 | Width of road ( 2- lane) | 9 m |
| 7 | Road type and structure | Flexible pavement |

Please check ‘*Assumptions and data for tool*’ tab in the tool to view the complete list of assumptions.



# Scenario analyses

# Scenario analyses: Overview

**In order to demonstrate the capabilities of the tool and how it can help LMCC in decision making, two scenarios were analysed:**

**Scenario 1 evaluates the environmental impacts of a road built using three types of asphalt:**

*Conventional asphalt with 30% RAP (Baseline) || Conventional asphalt with 50% RAP (Option 1) ||*
*Custom mix asphalt with 30% RAP and 1% toner (Option 2) ||*

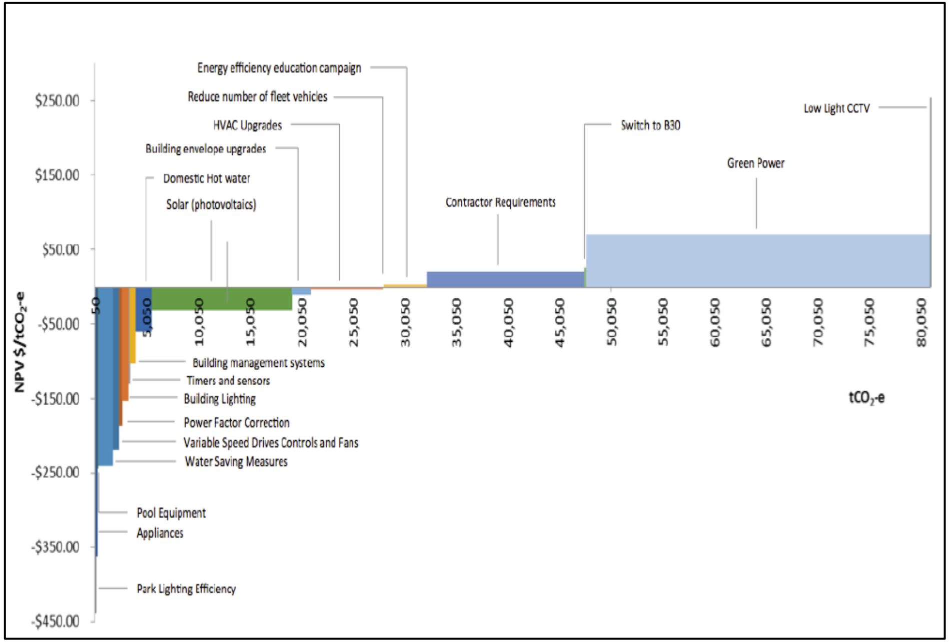
**Scenario 2 evaluates the influence of materials transportation distances on the environmental impacts of the road.**

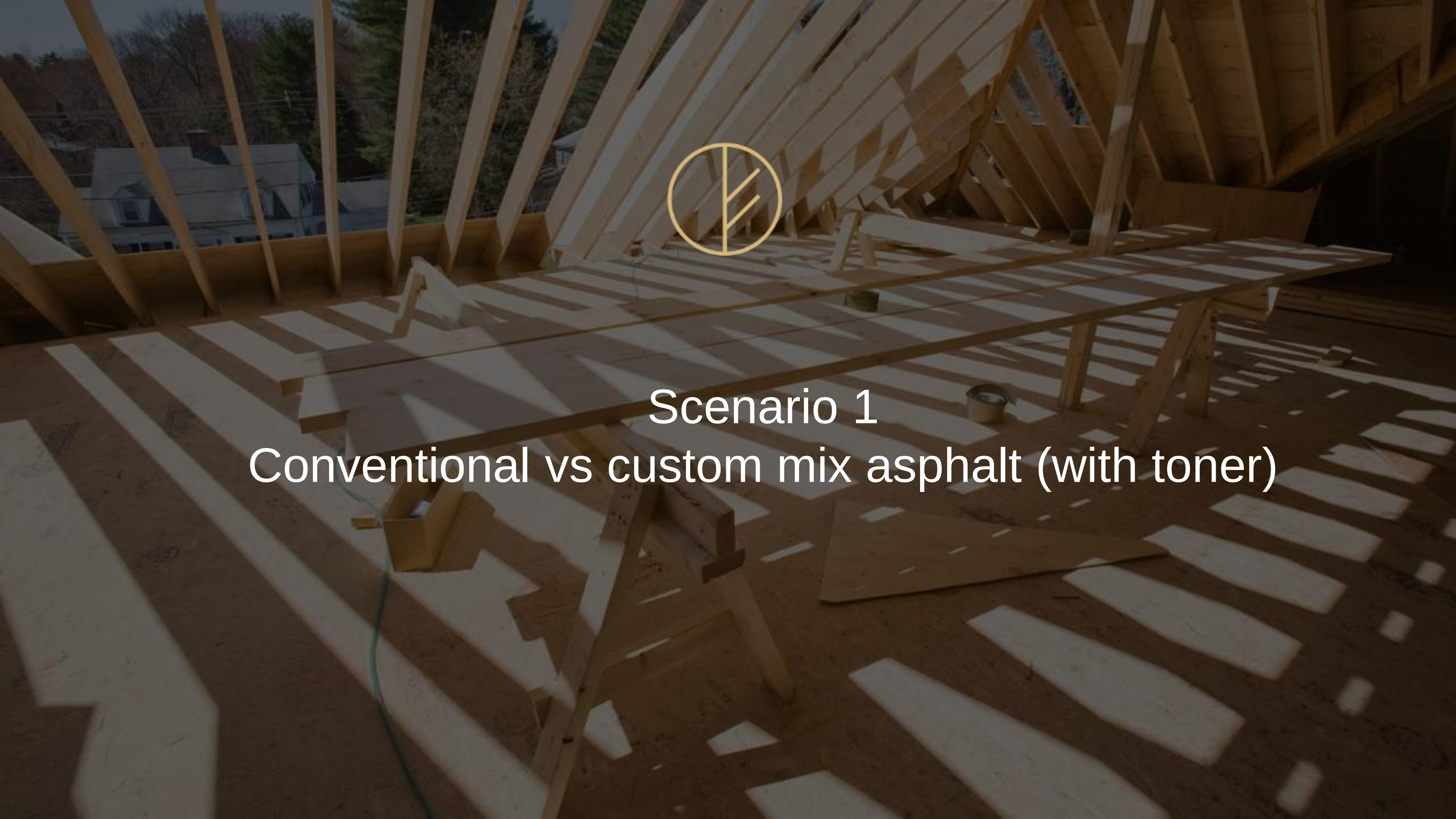
*For this scenario, the road structure and composition of the courses was kept similar for the baseline and the two options.*

Note: All input values of the scenario analysis are used to demonstrate the decision-making capabilities of tool and do not correspond to any particular project or case study

# Scenario analyses: Marginal abatement cost curves (MACCs)

- A MACC is a graphical representation of the potential and cost implications of opportunities to reduce emissions.
- The tool uses MACCs to provide a high-level representation of both the cost and abatement potential of each option in a typical project.
- Each block on the graph represents a different initiative, with the width of a block representing embodied carbon reduction potential and the height showing the average net cost of abatement of one tonne of $CO_2$eq under that initiative.
- The graph is ordered left to right in order of low to high cost with any blocks below the central X-axis being cost negative.





# Scenario 1

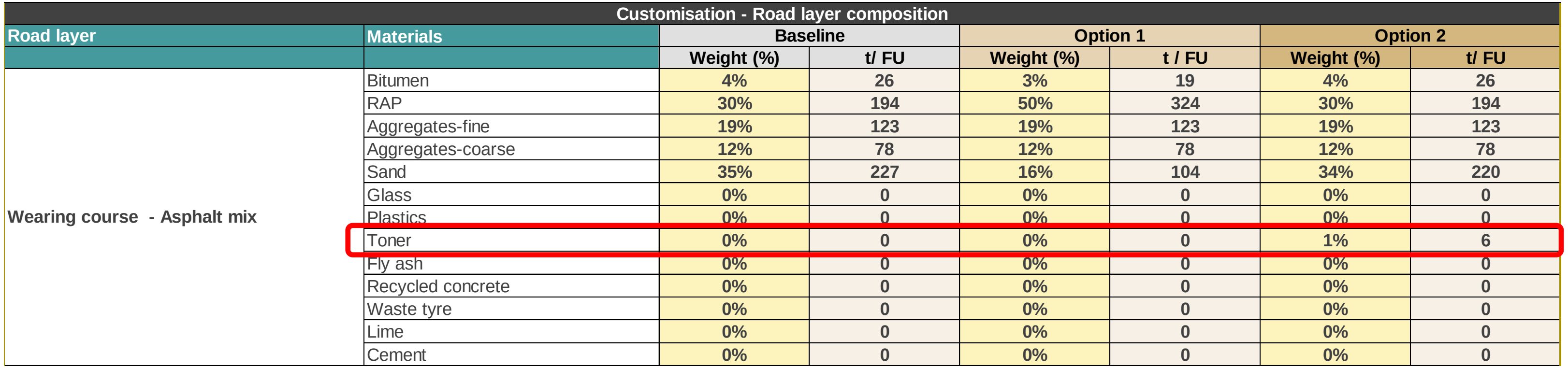
## Conventional vs custom mix asphalt (with toner)

# Scenario 1: Key Parameters

- **Scenario 1 evaluates the environmental impacts of a road built using three types of asphalt:** *Conventional asphalt with 30% RAP (Baseline) || Conventional asphalt with 50% RAP (Option 1) || Custom mix asphalt with 30% RAP and 1% toner (Option 2) ||*
- The custom mix (e.g., Reconophalt) contains additives such as toner, which can enhance its service life and result in the road requiring only 1 resurfacing over its 40-year lifespan, compared to 2 for its conventional counterpart.
- The tool enables users to input the material composition for both types of asphalt and other key parameters such as resurfacing intervals, transport distances, etc.
- Based on these inputs, the tool evaluates and compares various environmental impacts, including carbon, for a road built using conventional vs sustainable asphalt.
- The tool also allows users to input material costs for the various course e.g., wearing, base, and subbase and provides high level insights to compare the costs (savings/ expense) vs carbon reduction via Marginal Abatement Cost Curves.

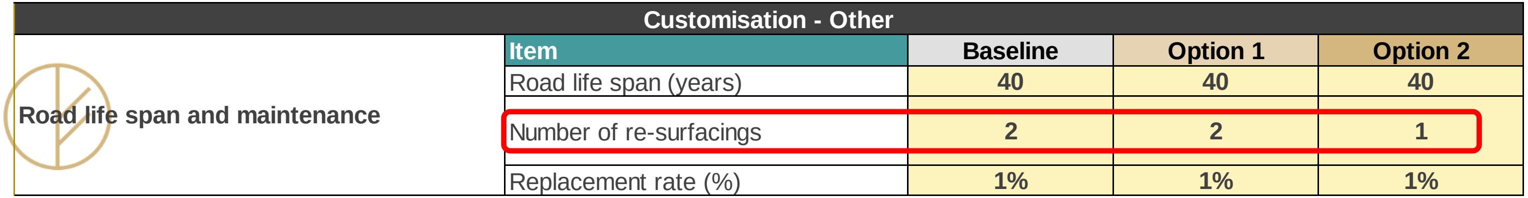
# Scenario 1: Tool Inputs (Materials and maintenance)

- The ‘Baseline’ and ‘Option 1’ are conventional mixes with 30% and 50% RAP respectively, and no customised additives
- For Option 2, 1% waste toner is introduced in the mix which replaces an equivalent amount of sand.
- While the Baseline and Option 1 require two resurfacings, the custom mix i.e., Option 2 requires only one



**Customisation - Road layer composition**

| Road layer | Materials | Baseline | | Option 1 | | Option 2 | |
|---|---|---|---|---|---|---|---|
| | | Weight (%) | t/ FU | Weight (%) | t / FU | Weight (%) | t/ FU |
| Wearing course - Asphalt mix | Bitumen | 4% | 26 | 3% | 19 | 4% | 26 |
| | RAP | 30% | 194 | 50% | 324 | 30% | 194 |
| | Aggregates-fine | 19% | 123 | 19% | 123 | 19% | 123 |
| | Aggregates-coarse | 12% | 78 | 12% | 78 | 12% | 78 |
| | Sand | 35% | 227 | 16% | 104 | 34% | 220 |
| | Glass | 0% | 0 | 0% | 0 | 0% | 0 |
| | Plastics | 0% | 0 | 0% | 0 | 0% | 0 |
| | Toner | 0% | 0 | 0% | 0 | 1% | 6 |
| | Fly ash | 0% | 0 | 0% | 0 | 0% | 0 |
| | Recycled concrete | 0% | 0 | 0% | 0 | 0% | 0 |
| | Waste tyre | 0% | 0 | 0% | 0 | 0% | 0 |
| | Lime | 0% | 0 | 0% | 0 | 0% | 0 |
| | Cement | 0% | 0 | 0% | 0 | 0% | 0 |

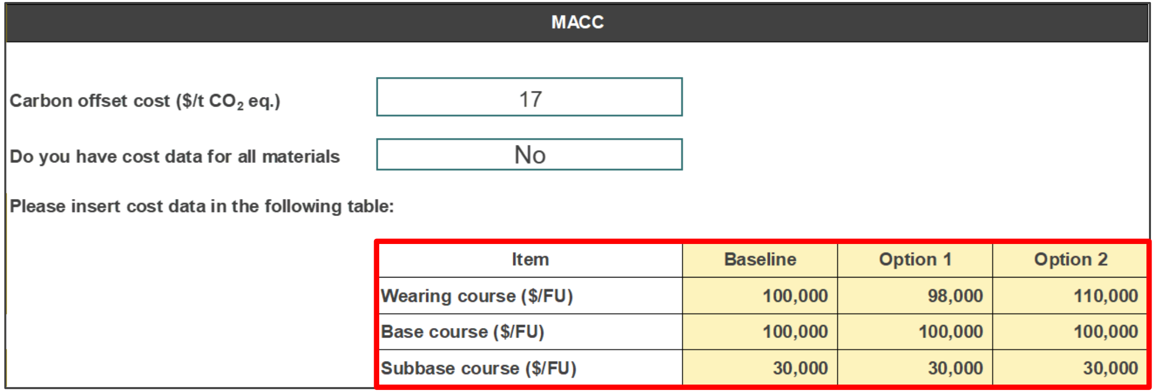


**Customisation - Other**

| | Item | Baseline | Option 1 | Option 2 |
|---|---|---|---|---|
| Road life span and maintenance | Road life span (years) | 40 | 40 | 40 |
| | Number of re-surfacings | 2 | 2 | 1 |
| | Replacement rate (%) | 1% | 1% | 1% |

# Scenario 1: Tool inputs (Costs)

- It was assumed that the 50% RAP mix (Option 1) was 2 % cheaper, while the custom mix (Option 2) 10% more expensive than the baseline.
- The price of an Australian Carbon Credit Unit (ACCU) was input as \$17/ $tCO_2$ eq. based on the present market scenario



**MACC**

**Carbon offset cost (\$/t $CO_2$ eq.)** 17

**Do you have cost data for all materials** No

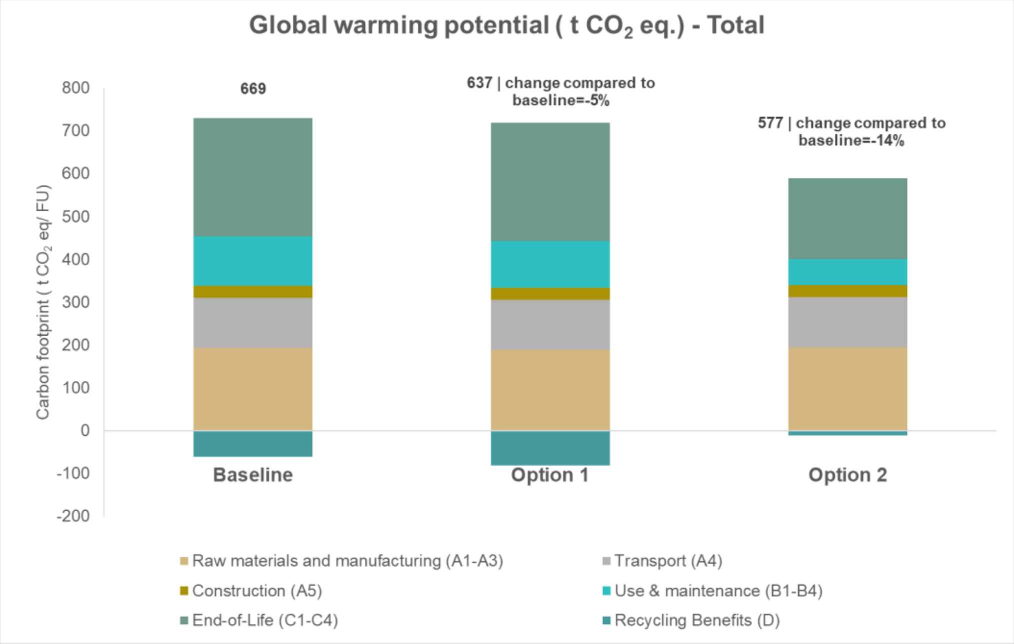
**Please insert cost data in the following table:**

| Item | Baseline | Option 1 | Option 2 |
|---|---|---|---|
| Wearing course (\$/FU) | 100,000 | 98,000 | 110,000 |
| Base course (\$/FU) | 100,000 | 100,000 | 100,000 |
| Subbase course (\$/FU) | 30,000 | 30,000 | 30,000 |

*Note: All input values of the scenario analysis are used to demonstrate the decision-making capabilities of tool and do not correspond to any particular project or case study. The costs depicted are dummy values and should be replaced with actuals when available.*

# Scenario 1: Results (Global Warming Potential)

- The custom mix (Option 2) offers **14% reduction** in carbon emissions compared to the baseline mix with 30% RAP. This is mainly due to the reduced number of resurfacings compared to the baseline.
- The 50% RAP conventional mix (Option 1), also results in lower carbon emissions **(5%)** compared to the baseline.
- This is due to higher recycled content in the mix. However, since the number of resurfacings required for Option 1 and the baseline mix are assumed to be similar, its reduction potential is significantly lower compared to the custom mix.



*Recycling benefit (D) is the potential environmental benefit due to avoided production of virgin materials. This can happen when materials from an asset at its end-of-life are recycled/ reused to substitute virgin materials for other applications. In LCAs, emissions to the environment i.e., environmental impacts are represented as positive, whereas benefits are represented as negative i.e., below the x-axis, to convey the fact that they help in reducing the emissions.*

*Note: This result is to be viewed in conjunction with the assumptions listed in the tool. Changing the assumptions will alter the results.*

# Scenario 1: Results (Global Warming Potential)

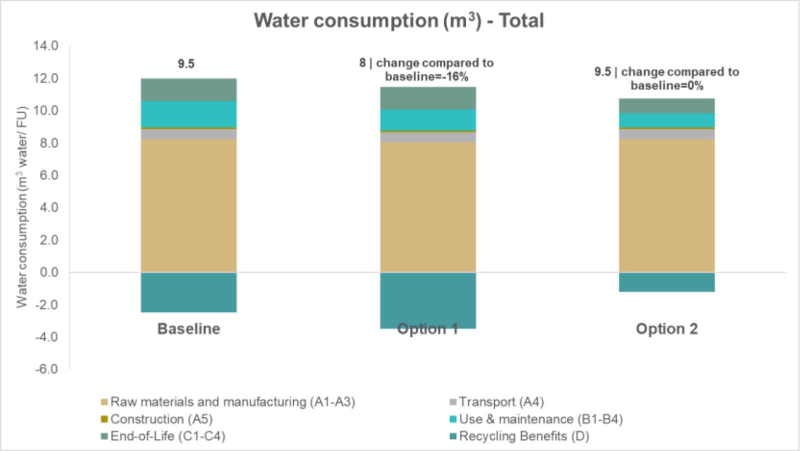
The results in this scenario provide another insight - i.e., increasing recycled content or substituting virgin materials with their recycled counterparts can help in reducing carbon emissions, however it is also important to consider their value-add from a performance or functionality perspective.

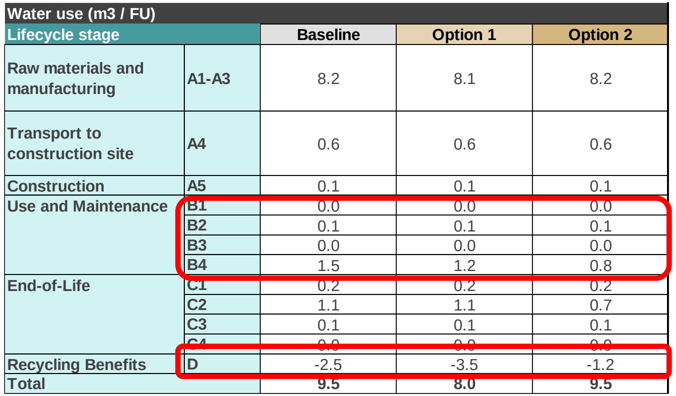
For example, in this scenario increasing the RAP content from 30% to 50% decreases the carbon footprint of Option 1 mix by 5% compared to the baseline. This also reduces the amount of virgin materials such as bitumen and aggregates/sand used in the wearing course.

However, the reduction offered by the Option 2 mix, which has similar RAP content to baseline is much greater i.e., 14%. The additives in the mix, such as toner, enhance the life span of the wearing course and reduce the number of resurfacings required. This lowers the amount of materials, transport, and utilities required for maintaining the road, eventuating to a much lower carbon footprint compared to the baseline and even the Option 1 mix with a higher recycled content.

# Scenario 1: Results (Water consumption)

- Although the overall water consumption remains similar for the road built with the custom mix asphalt (Option 2) and the baseline, the **maintenance stage** for the former has **47% lower water consumption,** on account of less number of resurfacings.
- The 50% RAP conventional mix (Option 1) has **16% lower** water consumption compared to the baseline, which is driven mainly by the increased recycled content and the benefits of recycling at the end-of-life of the road.





| Water use (m3 / FU) | | | | |
|---|---|---|---|---|
| **Lifecycle stage** | | **Baseline** | **Option 1** | **Option 2** |
| **Raw materials and manufacturing** | **A1-A3** | 8.2 | 8.1 | 8.2 |
| **Transport to construction site** | **A4** | 0.6 | 0.6 | 0.6 |
| **Construction** | **A5** | 0.1 | 0.1 | 0.1 |
| **Use and Maintenance** | **B1** | 0.0 | 0.0 | 0.0 |
| | **B2** | 0.1 | 0.1 | 0.1 |
| | **B3** | 0.0 | 0.0 | 0.0 |
| | **B4** | 1.5 | 1.2 | 0.8 |
| **End-of-Life** | **C1** | 0.2 | 0.2 | 0.2 |
| | **C2** | 1.1 | 1.1 | 0.7 |
| | **C3** | 0.1 | 0.1 | 0.1 |
| | **C4** | 0.0 | 0.0 | 0.0 |
| **Recycling Benefits** | **D** | -2.5 | -3.5 | -1.2 |
| **Total** | | **9.5** | **8.0** | **9.5** |

*Note: As there is only one resurfacing required for the road built with high-recycled content asphalt, the amount of material used in its the life cycle will also less compared to its conventional counterpart. This means there is less material to be recycled at end-of-life, which invariably reduces the recycling benefits in module D.*

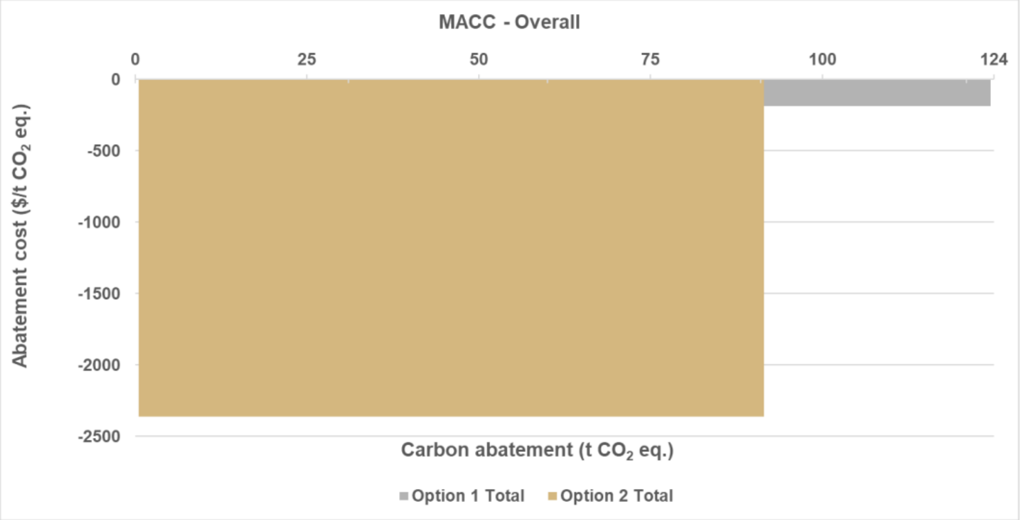
*In this case the net effect of reduced water impacts during maintenance and recycling benefits translates to almost similar water consumption figures for conventional and high-recycled content asphalt. Results may vary with different material compositions and assumptions.*

# Scenario 1: Results (MACC)

Despite being 10% more expensive than the baseline, the custom mix offers a saving of **$2,400 per tonne of carbon abated.** This means that the custom mix can provide both carbon and cost savings.

The 50% RAP mix (Option 1) provides a saving of **$185 per tonne of carbon abated**. This is to be expected as it was assumed to be 2% cheaper than the baseline.

Both results are to be interpreted with respect to the baseline mix.



*Note: All input values of the scenario analysis are used to demonstrate the decision-making capabilities of tool and do not correspond to any particular project or case study.* ***The costs depicted are dummy values and should be replaced with actuals when available.***

# Scenario 1: Results (Cost to go carbon neutral)

- The graph shows the costs involved for going carbon neutral at a project level – which in this case is a **‘1 km road with two lanes’**, built using the three types of asphalt mixes i.e., 30% RAP mix (Baseline), 50% RAP mix (Option 1) and Custom mix with 30% RAP and 1% toner(Option 2).
- Given that the 50% RAP mix and Custom mix provide a **5% and 14% reduction** in carbon emissions, the cost required to go carbon neutral by offsetting the remainder emissions through purchase of carbon credits is lower by the same percentage than the baseline.
- Furthermore, the emissions reductions that were obtained through initiatives such as higher recycled content and reduced number of resurfacing are cost negative, as depicted by the grey bars below x-axis.

# Scenario 1: Results (Cost to go carbon neutral, contd.)

A summary of the key findings at a project level can be found in the table below

| | **Baseline** | **Option 1** | **Option 2** |
|---|---|---|---|
| **Carbon footprint (t $CO_2$ eq.)** | 669 | 637 | 577 |
| **Project cost ($)** | $ 431,000 | $ 424,980 | $ 351,100 |
| **Carbon abatement cost ($)** | $ 11,378 | $ 4,807 | -$ 70,086 |
| Offset cost ($) | $ 11,378 | $ 10,827 | $ 9,814 |
| Initiative cost ($) | $ - | -$ 6,020 | -$ 79,900 |

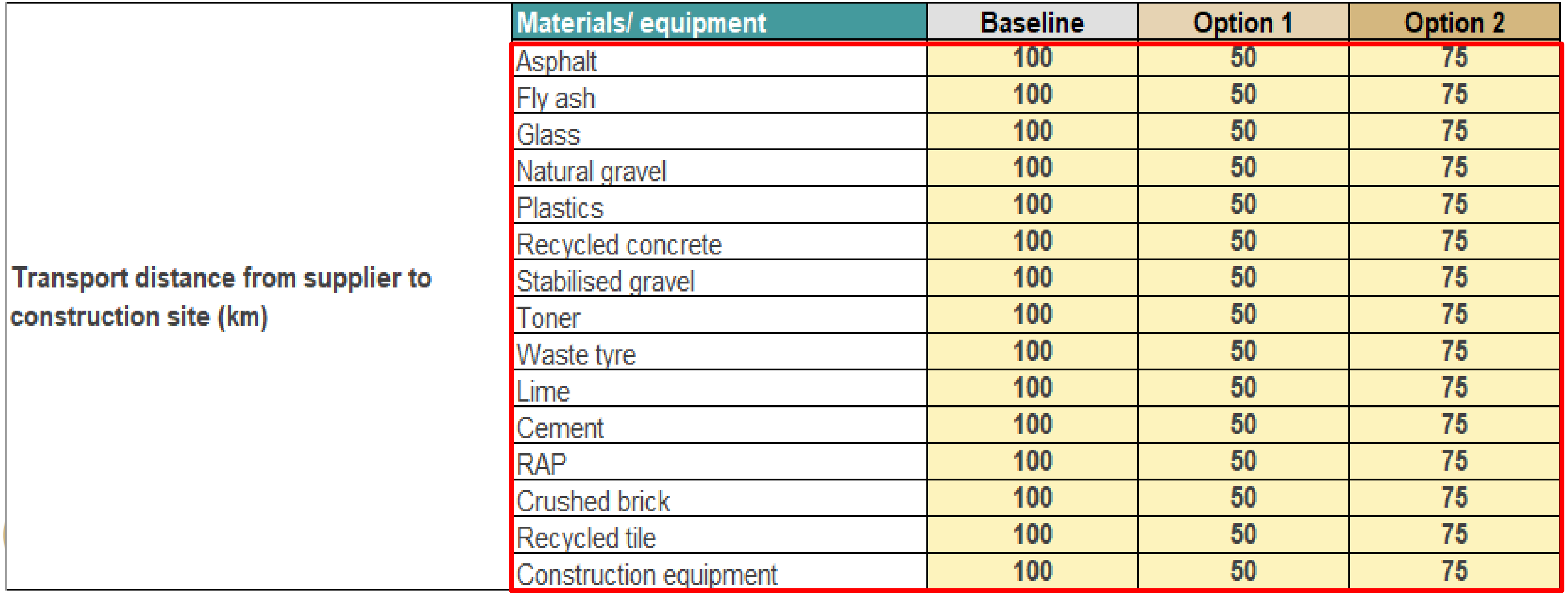
*Note: All input values of the scenario analysis are used to demonstrate the decision-making capabilities of tool and do not correspond to any particular project or case study.* ***The costs depicted are dummy values and should be replaced with actuals when available.***

# Scenario 2

## Influence of materials transportation distance

# Scenario 2 – Inputs (Materials transportation distance)

In this scenario, only the transportation distance has been varied. The materials composition for the baseline and the two options is kept identical i.e., conventional mix with 30% RAP

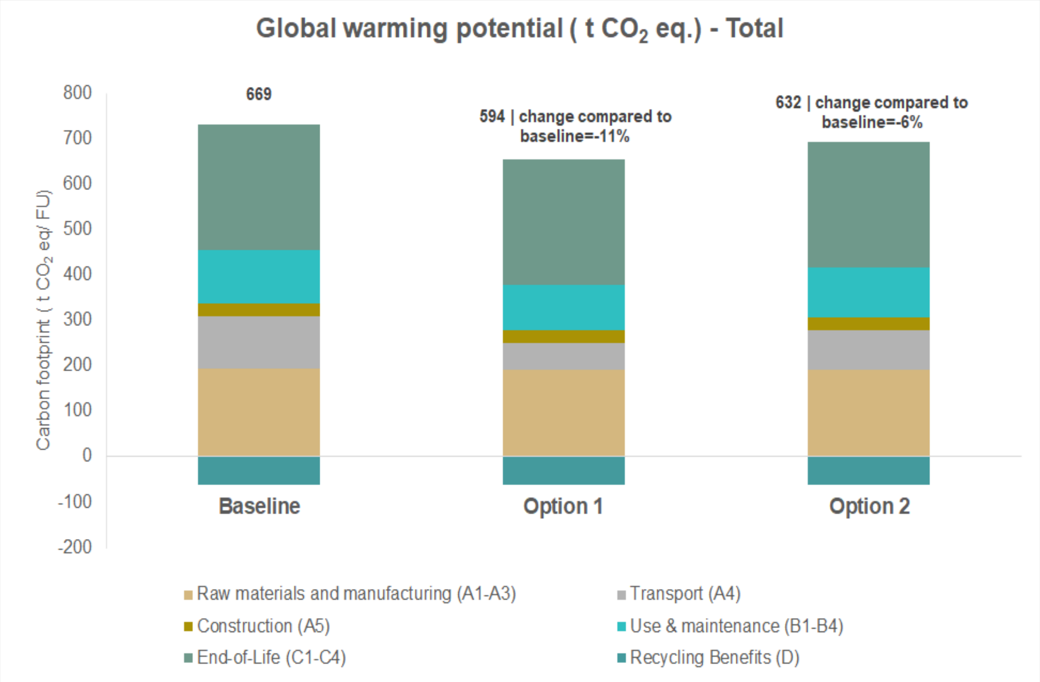


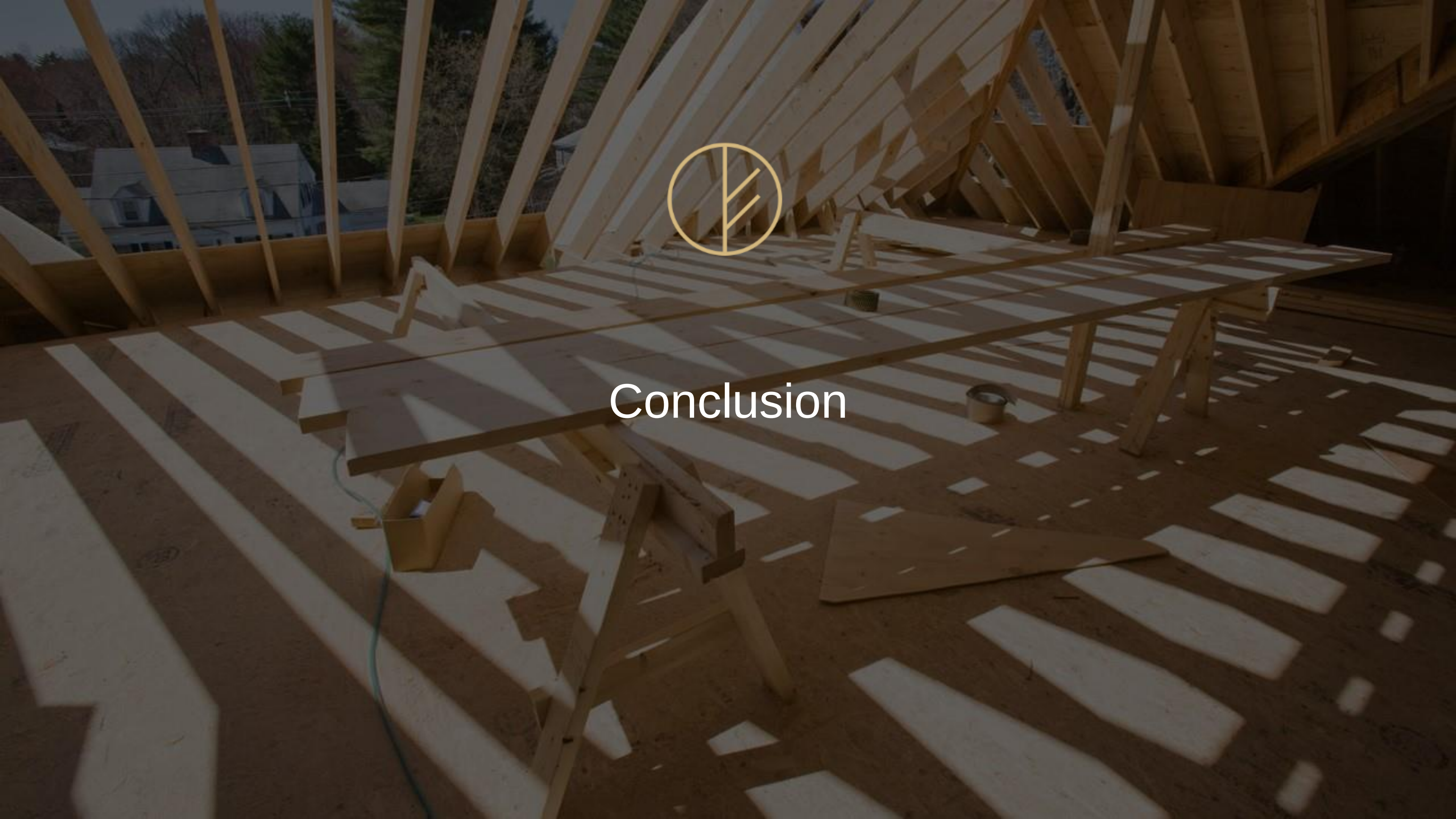
| | Materials/ equipment | Baseline | Option 1 | Option 2 |
|---|---|---|---|---|
| **Transport distance from supplier to construction site (km)** | Asphalt | 100 | 50 | 75 |
| | Fly ash | 100 | 50 | 75 |
| | Glass | 100 | 50 | 75 |
| | Natural gravel | 100 | 50 | 75 |
| | Plastics | 100 | 50 | 75 |
| | Recycled concrete | 100 | 50 | 75 |
| | Stabilised gravel | 100 | 50 | 75 |
| | Toner | 100 | 50 | 75 |
| | Waste tyre | 100 | 50 | 75 |
| | Lime | 100 | 50 | 75 |
| | Cement | 100 | 50 | 75 |
| | RAP | 100 | 50 | 75 |
| | Crushed brick | 100 | 50 | 75 |
| | Recycled tile | 100 | 50 | 75 |
| | Construction equipment | 100 | 50 | 75 |

# Scenario 2: Results (Global Warming Potential)

- As depicted in the graph, reducing materials transportation distance can provide substantial reduction in the carbon emissions of the road’s life cycle.
- Sourcing of materials from local suppliers should therefore be priortised where possible

Note: Other aspects such as effect of reduced transportation distances on water consumption, MACCs, etc. can be interpreted in the same way as Scenario 1. These have not been provided for Scenario 2.





# Conclusion

# Conclusion

- The Excel based tool provides LMCC with the capability to evaluate the effect of various parameters such as materials type, road structure, recycled content, transport distances on the environmental footprint of a road.
- It also allows the input of materials and transportation costs and provides high-level insights into carbon abatement costs via marginal abatement cost curves (MACCs).
- Overall, the tool can be a powerful decision-making instrument for LMCC to assess the use of recycled materials in road construction.
- There is a high level of uncertainty involved in the factors (background data) for the ecotoxicity indicators. The assessment of environmental fate of the materials using these indicators requires additional data and research. Edge recommends that further research be undertaken/ commissioned on this topic before publishing the results form these indicators or using them for decision making.
- The tool can be updated by an LCA practitioner to include additional materials and latest environmental impact factors. We recommend that LMCC do a yearly review with Edge to ensure that the LCA database in the tool is up to date.

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