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# The Race Toward Carbon Neutral Ecotourism: Leveraging Life Cycle Analysis and Natural Climate Solutions for a Community Adventure Event

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# The Race Toward Carbon Neutral Ecotourism: Leveraging Life Cycle Analysis and Natural Climate Solutions for a Community Adventure Event

By

Ted Tarricone

Accepted in Partial Completion
of the Requirements for the Degree
*Master of Science*

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# The Race Toward Carbon Neutral Ecotourism: Leveraging Life Cycle Analysis and Natural Climate Solutions for a Community Adventure Event

A Thesis
Presented to
The Faculty of
Western Washington University

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# Abstract

Global tourism is an interconnected framework of industries that is influenced by and has impacts on economic, social, and environmental structures. Currently, tourism accounts for roughly 8% of global greenhouse gas emissions, and that is expected to increase with the industry's growth projections. With a dependence on nature, one tourism subset predisposed to environmental study is ecotourism. To develop a scalable system for ecotourism assessment, emission reduction, and solutions to meet carbon neutrality, a small (n=3894 participants) adventure relay race named Ski to Sea in Bellingham, WA was examined. A life cycle analysis (LCA) conducted on the race showed similar proportional results to other tourism LCAs, where transport made up over 80% of the 325 tonnes of $CO_2e$ emitted in connection with the 2023 race. Life cycle management (LCM) techniques were then employed to determine various reduction potentials, and opportunities for reducing race emissions by 11-53% were identified. For the remainder, an offsetting system based on natural climate solutions (NCS) through a carbon trust network was assessed. With a shared basis in nature and community, ecotourism and NCS strategies can provide a reciprocal relationship with multiple co-benefits. An estimate of $3.93-8.37 per participant is estimated to financially cover the implementation of local biochar projects to achieve carbon neutrality for Ski to Sea, depending on reduction measures taken. Further research into standardized and accessible LCM techniques, NCS capacity, and voluntary carbon market pricing and mechanisms would allow for a wider implementation of these principles, while re-imagining the administration of ecotourism at large may be considered as a different pathway for decarbonizing the industry.

# Acknowledgements

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To my mom, Bonnie, you have instilled in me a sense of love in the world, how to connect with the humanity of each individual with whom my path crosses, and to move through the world with integrity. To my dad, Lee, your inspiring curiosity and joy in learning about the world has helped me connect with each place I find myself, with a corresponding collection of aphorisms that always seem to spring to mind at just the right moment. To Lydia, your vibrant colors and appreciation for the world's beauty illuminate the good that abounds in this world, a goal ever worth striving for. And to Pauly, your embrace of pushing for a more just, caring, and impassioned world inspires me to do the same.

To Em, your loving support over these years has kept me balanced, your expressions of fun kept me from the malaise, and your nourishing food kept me alive. To Shaz, you have kept me tethered to hope and the joy of exploring ideas, and to Fritz, you have instilled a sense of empathy and understanding in how I perceive and interact with the world. To the countless other friends and loved ones, your inspirations and influence have been an ever-guiding light.

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# List of Acronyms

AT – Alternative Tourism

$CO_2e$ – Carbon Dioxide Equivalent

F&B – Food and Beverage

GHG – Greenhouse Gas

LCA – Life Cycle Analysis

LCM – Life Cycle Management

NBS – Nature-Based Solutions

NBT – Nature-Based Tourism

NCS – Natural Climate Solutions

NR – Nature Relatedness

# Part I: Life Cycle Analysis in Ecotourism

# Chapter 1: Tourism and Climate Change

Global tourism acts as both an economic force and a significant contributor to greenhouse gas (GHG) emissions on a worldwide scale. Estimated to account for 7% of global exports, and with an annual growth estimate of 3-4% through 2030, tourism will continue to impact the financial wellbeing of both advanced and emerging economies for the foreseeable future (Lenzen et al., 2018). Though the COVID-19 pandemic deeply disrupted the industry, the UN World Tourism Organization underscores its potential for equitable and sustainable commerce for the future (UNWTO & UNEP, 2019). The emissions data have not been fully updated since these industry-wide shifts, but Lenzen et al. demonstrated that tourism accounted for around 8% of global emissions pre-COVID annually, at between 3.9 and 4.5 Gt$CO_2$e (2018).

*Figure 1 A map showing international arrivals and tourism expenditures for 2015 (UNWTO, 2016)*

Overwhelmingly, tourism's growth is currently projected to increase greenhouse gas emissions (UNWTO & International Transport Forum, 2019). Though strides have been made in decreasing emissions with improvements in tourism-related technologies and systems, growth in the industry has led to a net increase in related $CO_2$e emissions at large (Lenzen et al., 2018). A

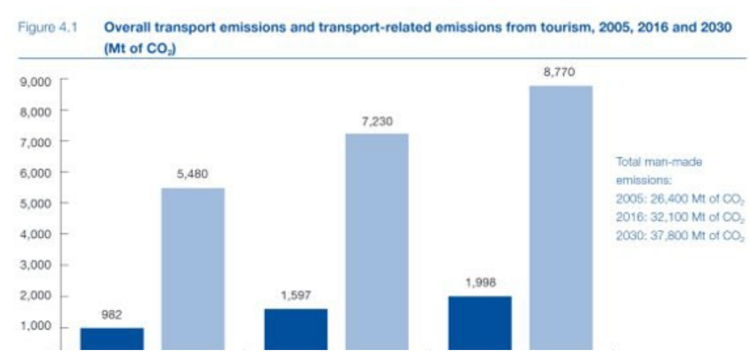

*Figure 2 (Transport-related Co2 Emissions of the Tourism Sector, UNWTO, 2019)*

number of tourism-related categories are responsible for such emissions, but transportation has been found to account for the majority of emissions, particularly with respect to air travel (Kitamura et al., 2020; Lenzen et al., 2018; Sharp et al., 2016; Spasojevic et al., 2018). As Spasojevic et al. describe, the connection between tourism and air travel in particular has increased over time and is characterized by a mutual dependence for development. Additionally, it is projected that airline carbon dioxide emissions will increase by a factor of between 2.0 and 3.6, and nitrogen oxide emissions will increase by a factor between 1.2 and 2.7 from 2000 to 2050 (Owen et al., 2010). This identified relationship assumes that a proportion of this increase will be attributable to tourism by proxy. It is estimated that between 50% and 55% of international arrivals are attributable to leisure, recreation, or holiday (Gössling et al., 2013; Spasojevic et al., 2018). In addition to transport as the most prominent emissions category, other elements of tourism will increase GHG emissions as the industry continues to grow. Myriad studies have identified lodging, food and beverage (F&B), shopping, entertainment, and changes in personal behavior as contributors to GHG emissions associated with tourism (Gössling et al., 2013; Kitamura et al., 2020; Filimonau, 2015; Nofriya et al., 2022; Sharp et al., 2016).

Tourism's dependence on an array environmental, economic, and social factors highlights a need for a collaboration among the various stakeholders that facilitate it as an industry to enact change (UNWTO & UNEP, 2019). From power production to agriculture, public infrastructure to community practices, tourism is entrenched in the various underpinnings of both the departing and arrival locales. In order to facilitate equitable economic development, while considering the impacts of greenhouse gas emissions on the planet's climatic future, growth must be accomplished with decarbonization (*Glasgow Declaration*, 2021). During COP 26 in Glasgow, a formal commitment that outlined a pathway to cultivating sustainable tourism was declared and further refined from previous declarations. This presented a strategy by which the industry's recovery from COVID-related setbacks could employ sector-transforming methods that ensure planetary health and human equity. The five shared pathways that compose this commitment are as follows:

- *Measure:* account for and disclose travel and tourism-related emissions in a standardized way
- *Decarbonize:* set and deliver targets across the many different factors that compose the travel sector without heavily leaning on carbon offsets
- *Regenerate:* restore and protect natural ecosystems to absorb carbon and protect biodiversity
- *Collaborate:* Share information and solutions among government agencies, private companies, visitors, and stakeholders alike
- and *Finance:* ensure sufficient resources to meet these goals and provide fiscal strategies to maintain effectiveness (*Glasgow Declaration*, 2021).

These are strategies that have continued to evolve over decades, and their implementation on a widespread scale presents both opportunities and challenges among the variety of tourism sub-categories.

*Opportunities in Alternative Tourism in Advancing Travel Sustainability*

One such sub-category that has shown potential for environmental improvement both thematically and in practice is that of alternative tourism (AT). Generally, AT is a collection of tourism strategies that aim to address and mitigate some issues that arise from conventional mass tourism, such as environmental and community degradation. AT can be further subdivided into a variety of further sectors, within which nature-based tourism (NBT) and adventure tourism are encompassed by the likes of ecotourism (Fennell, 2020). Figure 3 presents a basis for visualizing such a hierarchy (Belonozhko et al., 2022).

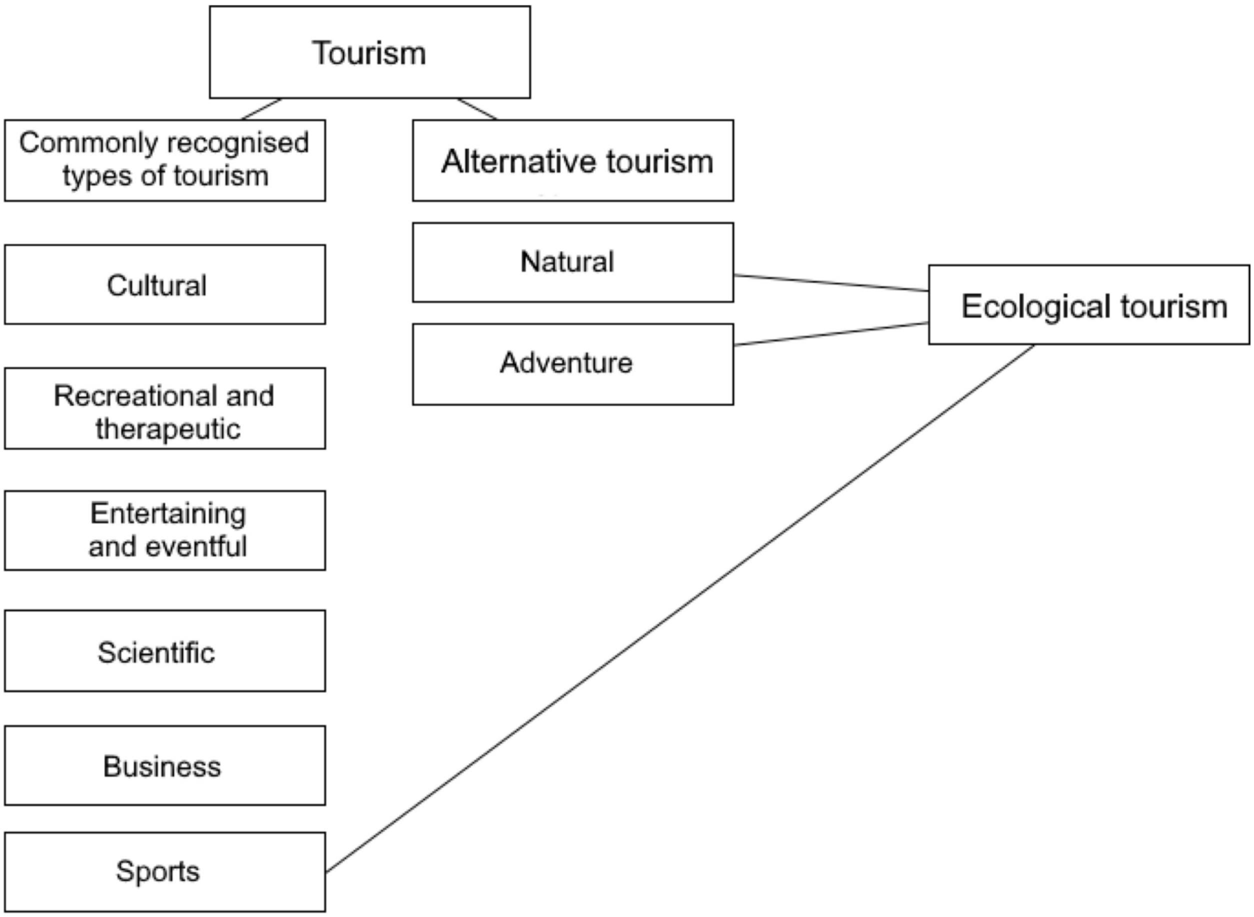


*Figure 3 A hierarchical representation of tourism (Belonozhko et al., 2022)*

As Fennel further describes, four of the main pillars that would define a responsible form of alternative tourism include:

1. Minimum environmental impact
2. Minimum impact on, with accompanying respect for, host cultures
3. Grassroots economic benefits that predominantly stay local
4. Recreational satisfaction for visitors (2020).

It can be seen that alternative tourism, along with its sub-categories, is defined by the holistic consideration to the destination's environment, people, and economy. These tenets are then used to define ecotourism as a "sustainable form of natural resource-based tourism that focuses primarily on experiencing and learning about nature, and which is ethically managed to be low-impact, non-consumptive, and locally-oriented (control, benefits, and scale)" (Fennell, 2020).

Ecotourism's focus on nature, while encompassing a variety of tourism enterprises (naturalism, wildlife viewing, adventure tourism, outdoor sports, among others), positions it as a suitable subject to better understand and implement practices that minimize environmental damage. As discussed previously, a vast majority of tourism in its current form is dependent on GHG emitting technologies; ecotourism is no exception. Thus, the foundational ethos for ecotourism predisposes it as an area that can be at the forefront of necessary GHG mitigation efforts in the greater industry.

*Ecotourism's attitudes, participants, and relations to the natural world*

The social constructs that characterize ecotourism are one element that define it as a suitable candidate for developing emission reductions in tourism. In an exploration as to how individuals' connection with nature relates to environmental concern and behavior, Nisbet et al. devised a construct coined Nature Relatedness (NR) (2009). They describe in the *biophilia hypothesis* that humans have an innate desire to relate to the natural environment (Kellert & Wilson, 1993; Nisbet et al., 2009). The NR framework builds on this identified inclination for nature, clarifying how time spent in and appreciation for the outdoors is connected to increased environmental concern with a more robust and developed ecological perspective in mindset and personal behavior. Nisbet et al. suggest that such a dynamic can be an important tool in educating people regarding environmental issues and their individual behaviors (Nisbet et al., 2009).

Though considerable research has been conducted and shows a connection between outdoor recreation and environmental attitudes, little exists that specifically look at how such recreation influences views on climate change. Knight and Hao specifically studied the relationship between such activities and concerns for climate change (2022). They found that there is a positive, significant correlation between outdoor recreation and concern for climate change. However, it was noted that this concern was particularly tied to a sense of *enjoyment* while in nature. Such attribution of concern led the authors to conclude that cultivating more instances of "meaningful, enjoyable nature-based" experiences would confer greater concern regarding climate change (Knight & Hao, 2022). Since the tourism industry is predicated upon devising and curating experiences for consumers, the reported relationship is one that could be woven into itineraries to facilitate a better understanding and care for climate issues.

Given that education can be a prominent element in ecotourism (Fennel, 2008, pg. 22), the works outlined here identify the underlying connections that would facilitate it as a means for climate-related pursuits. Mondino and Beery explain how ecotourism can be an effective learning tool for participants, operators, and community members alike (2019). The cooperation and shared understanding among the various stakeholders are central to a defined necessity of ecotourism to comprehensively maintain resources (Jacobson & Robles, 1992; Mondino & Beery, 2019). This concept can be extended past the specific landscapes, rivers, forests, and wildlife to the climate at large which facilitates their continuity. Ecotourism can be an effective catalyst for creating learning experiences that harmonize conservation and sustainable development, since the interface in the space is that between small groups and locally-owned, small-scale businesses. Oftentimes, this exchange occurs in rural locales (Mondino & Beery, 2019). Examples of this intersection of development, conservation, and education can be seen in Tortuguero National Park in Costa Rica (Jacobson & Robles, 1992) and Amazonian regions in Ecuador, Peru, and Bolivia (Stronza & Gordillo, 2008). Additionally, Powell and Ham describe how ecotourism is used in the Galapagos Islands to increase knowledge of the area and cultivate supportive attitudes towards resource management, environmental behavior, and conservation (2008). Opportunities exist to further educate and connect ecotourism participants and stakeholders with various methods for reducing and mitigating GHG emissions.

*Activity-focused susceptibilities to climate change*

These underlying social, commercial, and psychological constructs are coupled with climate change's direct impacts to the natural spaces within which ecotourism takes place. As climate change continues to alter or damage ecosystems, so too there will be pressures on outdoor recreation and ecotourism, by proxy. Increasingly, visitor and management adaptation have been required to continue facilitating the myriad activities that utilize natural environments (Miller et al., 2022). With time, however, adaptation and resilience may lose efficacy in many realms of outdoor recreation. As climate change continues to rapidly alter ecosystems, the overall character of some pursuits may change drastically. One clear impact of climate change is increasing average global temperature, which already acts as a major determinant in recreation participation (Miller et al., 2022). Visitation habits will shift in many environs. Shoulder seasons could see increased participation due to warmer periods than what has historically been the case, while the height of summertime could exhibit decreasing participation due to excess heat (Miller et al., 2022; R. Richardson & Loomis, 2004). For wildlife-based ecotourism, this heat will likely shift behavior and local populations in ways that may add challenges to consistent sightings, impacting ecosystem health and visitor satisfaction (Fuller et al., 2021).

Climate change can also impact ecosystems in ways which are projected to cause larger and more destructive wildfires. For instance, in the Western United States, closures of recreation and ecotourism sites are expected to increase due to wildfires and smoke, which impedes activity as normal, as well as disrupts nearby communities (Halofsky et al., 2022). Additionally, this may put increased pressure via increased visitation in adjacent areas that are not as directly impacted by fires (Halofsky et al., 2022). Reductions in visitations by both nonlocal (Sage and Nickerson, n.d.) and local participants (L. A. Richardson et al., 2012) would be representative of a natural area no longer able to support ecotourism capacity that could be linking conservation and local economic development.

Additionally, climate change can have marked effects on local hydrological cycles, impacting streams, rivers, and lakes. In the Western US, boating and angling are key sources of revenue for many areas; such inconsistencies could have marked impacts on participation and economic generation (Halofsky et al., 2022). According to Isaak et al., cold-water fish species are likely to decrease, which changes angling opportunities and aquatic ecosystems (2011). This unpredictability would apply to the winter season as well, harming an important economic engine in snow sports. Up to a 50% decrease of skiing in Western States is estimated to occur by 2050 (Wobus et al., 2017). Clearly, the physical effects of climate change could prove existential to innumerable stakeholders in ecotourism, prompting a vested interest to develop an industry-wide approach to such a broad problem.

These issues and considerations are compounded by the projected growth rates specifically regarding ecotourism. A compound annual growth rate (CAGR) has been estimated at 13.9% for a market size of $374.2 Billion by 2028 (*Ecotourism Market Size, Trends, Growth Industry Report 2023-2028*, n.d.) and by a different estimate a CAGR of 14.8% with a market size of over a trillion dollars by 2030 (Straits Research, n.d.). This is further supplemented by the Adventure Travel Society's estimates of 10-15% annual growth with respect to adventure tourism (Hudson, 2012). With such expected growth rates, emissions will continue to rise in this travel segment if a business-as-usual approach is taken to expansion and operations.

# Chapter 2: LCA in Tourism

In order to address the harmful impacts of tourism, as with GHG emissions, accurate and comprehensive assessment is a necessary, foundational step (Filimonau, 2015). Historically, holistic assessment regarding the industry's impacts has faced obstacles for accuracy and standardization. First, tourism is perhaps more appropriately described as a culmination of many different sectors and sub-sectors, rather than a single industry with clearly delineated bounds. An early gap in the research existed that did not address the non-operational sources of emissions with respect to the many aspects of tourism, such as supply chains, capital goods, retail shopping, and infrastructure (Filimonau, 2015; Patterson & McDonald, 2004). Additionally, the conceptual view of tourism as offering less tangible goods in the form of experience meant defining the scope for such analyses was difficult (Berno & Bricker, 2001; Filimonau, 2015). A chief advantage of using an LCA is the method's ability to account for "indirect" carbon contributions, providing a more holistic approach to quantifying emissions (Filimonau, 2015).

Further, Filimonau et al. argue that though a number of strategies exist for assessing tourism sustainability, life cycle assessment (LCA) doesn't suffer the same inaccuracies and unreliability that are exhibited in the others (2011). Table 1 outlines a number of these alternative methods and some of their limitations for assessment.

| Technique | Drawbacks | Source |
|---|---|---|
| Ecological Footprint Analysis (EFA) | Restricted capability to assess impacts with delayed/long-term effects | (Filimonau et al., 2011; Schianetz et al., 2007) |
| Carrying Capacity (CC) and Limits of Acceptable Change (LAC) | Limitations on conceptual feasibility and analytical coherence | (Filimonau et al., 2011) |
| Environmental Impact Assessment (EIA) | Narrow temporal and spatial scope, capable of handling only a limited number of impacts | (Filimonau et al., 2011; Schianetz et al., 2007) |
| Input-Output Analysis (IOA) | Applicability mostly restricted to macro-scales only, aggregation errors | (Filimonau et al., 2011) |
| Eco-Efficiency Analysis (EEA) | Focus on a relative environmental impact appraisal, less absolute | (Dyckhoff et al., 2015; Filimonau et al., 2011) |

*Table 1 Tourism impact analysis techniques*

Though imperfect, LCA offers a working solution to many of the obstacles faced in other methods when used within tourism. In addition to more comprehensive emission considerations, the technique can be applied across a variety of impact factors, depending on the study's aim. The most effective points for abatement, or hot spots, can be identified and used in management decisions (Filimonau, 2015). The ability to tailor the process to varied scopes, impact factors, and real-world applications gives LCA the ability to be used to increase the body of knowledge with many case studies, which can then be used to increase public awareness and understanding. However, these benefits can be hampered by the cost, time-intensiveness, database irregularities, and the same subjectivity that allows a researcher to focus efforts on particular impact factors influencing the narrative of the results (Filimonau et al., 2015).

A variety of tourism-based LCAs have been performed with different techniques to assess a variety of impact factors across locales. A collection of these can be seen below, as aggregated by Filimonau (2015).

| Study | Object of analysis | Primary environmental impacts assessed | Geographical scope |
|---|---|---|---|
| *Process-based LCA* | | | |
| Castellani and Sala (2012) | Holiday travel, including accommodation | A range of impacts | Italy |
| Filimonau et al. (2011a) | | Climate change | UK |
| Filimonau et al. (2014) | | | UK and France |
| El Hanandeh (2013) | Religious travel, including accommodation | | Saudi Arabia |
| Pereira et al. (2015) | Holiday travel, excluding accommodation | | Brazil |
| Filimonau et al. (2013) | Holiday package | | UK and Portugal |
| Kuo et al. (2005) | Tourist catering | A range of impacts | Taiwan |
| Michailidou et al. (2015) | Tourist accommodation | | Greece |
| König et al. (2007) | | | Portugal |
| Sára et al. (2004) | | | Italy |
| De Camillis et al. (2008) | | | |
| Cerutti et al. (2014) | | | |
| Filimonau et al. (2011b) | | Climate change | UK |
| Rosselló-Batle et al. (2010) | | | Spain |
| Li et al. (2010) | | | China |
| *Input-output LCA* | | | |
| Scheepens et al. (2015) | Sector of regional tourism | Climate change | The Netherlands |
| Berners-Lee et al. (2011) | Large tourism business | | UK |
| Patterson and McDonald (2004) | National tourism industry | | New Zealand |
| Cadarso et al. (2015) | | | Spain |

*Table 2 Comparison of LCAs conducted for in tourism (Filimonau, 2015)*

This list can be supplemented by further, more recent publications. Of an increasingly wide availability of research, a few notable studies include Sharp et al.'s focus on Iceland's tourism for a year (2016), Kitamura et al.'s exploration into tourism in Japan (2020), and a review that aggregated 80 documents regarding tourism LCAs (Herrero et al., 2022). In spite of the strides made in this field since the early 2000s, extending this research, and its adoption by proxy, remains vital. According to the UNWTO, only around 20% of tourism professionals reported being part of an organization that measured their total emissions (2023). Normalizing these techniques and implementing them on a far wider scale would both encourage further academic and organizational adoption of LCA in tourism. This study aims to utilize these techniques in new areas as a basis for expanding where and how LCA is applied.

## Backroads LCA: A Preliminary Analysis of Ecotourism

One increasingly popular category of ecotourism to which LCA techniques could be applied is in what is classified as active travel. Active travel involves different forms of movement through a place to experience it, including cycling, hiking, kayaking, and other assorted activities. In a step to address the LCA research gap at the meso-scale (Dolf, 2017), a preliminary foray into active travel was undertaken. This provided a framework for techniques, boundary considerations, and results to compare with both the existing literature and subsequent studies.

Backroads is a company that has specialized in active travel trips for over forty years, characterizing it as a suitable candidate for study. Currently, trips with Backroads are available in over fifty different countries and range in activity type and difficulty level (Backroads, n.d.). Cycling is involved in over half of the trips, as the primary focus or in combination with hiking and other activities. Virtually every trip itinerary is contingent upon experiencing the natural world through the defined activities and includes interacting with the local communities as a chief priority. Assessing a weeklong trip for a single itinerary provided a foundation for comparison with this paper’s more robust analysis that assesses a small, nature-based event in Bellingham, WA.

## Exploratory LCA Summary: Backroads Bozeman, MT to Jackson, WY Biking

This introductory LCA was conducted with three different boundaries for a single 6-day trip in the US Mountain West, considering different aspects of transportation, lodging, and food and beverage. Total emissions for a 16-person trip ranged from 1509 kg $CO_2e$ to 12,915 kg $CO_2e$, depending on which boundaries were chosen for the given itinerary. The primary emitting category was transportation, primarily from aviation in the highest emission boundary set. Further modeling from this study can provide Backroads a foundation for quantitative decision-making (Tarricone, 2022). Specific considerations worthy of expansion are included in the following sections to contextualize the direction and methods for the chief case study of this paper, the Ski to Sea event.

### Scope and Boundaries

The trip studied in this paper is Backroads' "Wyoming's Yellowstone & Tetons & Montana's Paradise Valley Bike Tour," one of multiple offerings in the greater Yellowstone region from the company. Picking up guests in Bozeman, MT and eventually dropping them off in Jackson, WY, the route visits Montana's Paradise Valley before winding southward through Yellowstone and Grand Teton National Parks (Backroads, n.d.). Given the variety of locales and activities encompassed by Backroads' trips, no single itinerary could be considered representative of the hundreds of others. However, this trip does exhibit many elements that characterize a majority of the company's itineraries. This travel plan takes place over the course of six days, stays in three different hotels, and typically uses two vans. A team of three leaders generally manages it (with exceptions made for unusually low enrollment). This trip primarily focuses on cycling, but there are other elements included, as with a half day of hiking and a half day of rafting.

There are a number of studies that describe a methodology for determining emissions from tourism (Kitamura et al., 2020; Lenzen et al., 2018; Sharp et al., 2016). One component of such analyses is defining the categories from which emissions originate. Using these papers as framework, categories that were directly pertinent to Backroads were identified and can be seen in the following “Expanded View Diagram” section. Instead of defining one set of boundaries, this study considered three cases to varying degrees. The first boundaries included emissions related to the defined categories from trip’s start in Bozeman to the trip’s end in Jackson. To supplement this, the next case incorporated the emissions tied to guest travel before and after the trip, as well as the lodging and dining that accompanies those travels. Finally, an exploration was performed with respect to the categories and subcategories that are most within Backroads’ ability to manage to provide a cursory basis for decision-making where company decisions can have the most immediate and effective impacts on emissions. The methods by which this study was performed were in accordance with the International Standard 14044, which describes a standardized, recognized system with which to approach conducting LCAs (ISO, 2006).

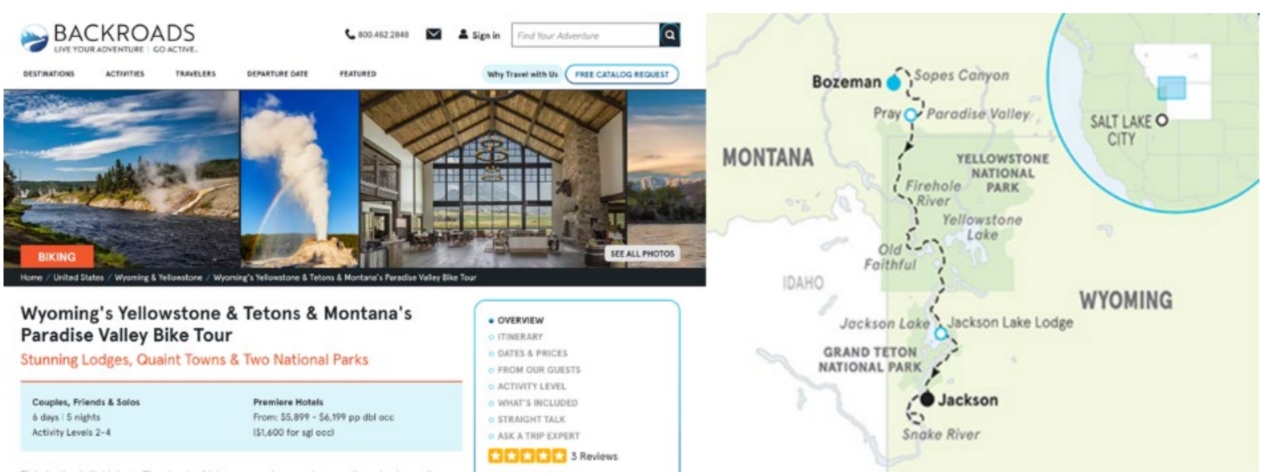


*Figure 4 Marketing materials for Bozeman to Jackson biking trip (Backroads, 2023)*

## Functional Unit

This study was centered around one functional unit, a single, six-day Backroads Bozeman to Jackson Biking Trip. The assumption for this single trip included 16 guests and three leaders, on the standard itinerary devised in advance for the season. In effect, the units here would be 16 guests' travel itinerary for six days (this unit is particularly applicable when comparing other Backroads itineraries but would need adjusting to compare to other tourism subcategories).

## Indicators Studied

The focus of this study was solely with respect to climate change potential. In future, more comprehensive studies, another avenue worth exploring would be regarding waste, which could include both trash generated and food leftovers.

## Expanded View Diagram

Below, an expanded view diagram represents the myriad sources from which emissions can originate for any given Backroads trip. With prior studies providing a framework for categorization (Kitamura et al., 2020; Sharp et al., 2016), categories for this study were chosen as follows: Transportation, Lodging, Food and Beverage, Vendor Activities, and Company System Infrastructure. The exploration of these elements provided a meaningful insight into the emissions released with respect to any given trip itinerary for the company. For this study, however, not every identified category was explored. The Vendor Activities category, outside of direct transportation emissions, was excluded based on the lack of standardization across the trip offerings and due to their relatively small contribution to trip activities overall. Additionally, Company System Infrastructure was excluded to a degree. Interim leader housing has been included in Lodging and leader transport in Transportation, so the remaining components in

Infrastructure have impacts spread across hundreds of trips globally. As a result, it was assumed that impacts in this realm are less impactful than those specifically chosen.

It is worth noting that this study did not include Scope 3 emissions that are present in many of these elements. Additionally, items encompassed by red dashes generally define areas Backroads would likely not be included in their decision-making matrix regarding immediate management decisions for curbing operational emissions.

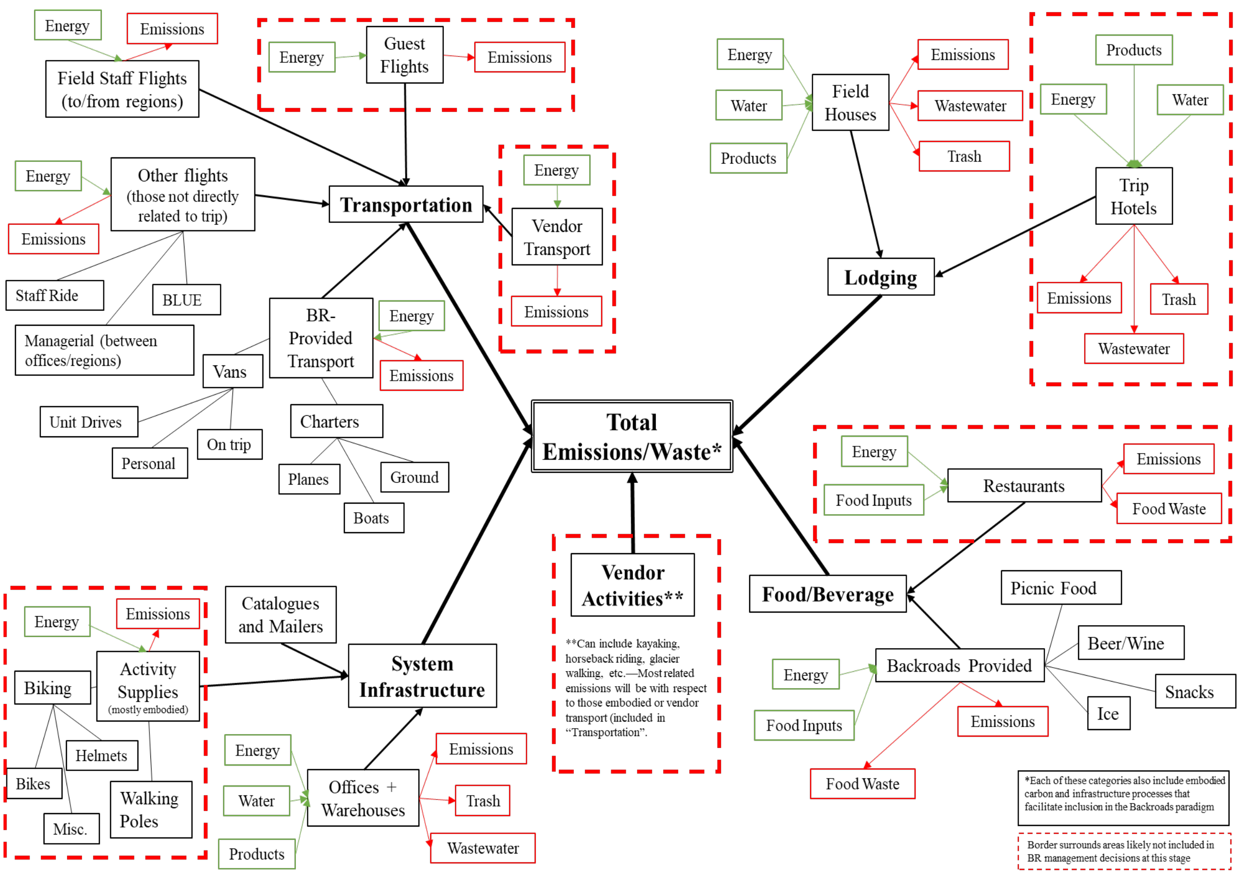


*Figure 5 Backroads trip expanded view diagram*

## Methods

Given the variety of emission sources associated with a trip like this one, an array of techniques for reasonable approximation were emulated from studies that focused on each individually or in some combination. Where multiple techniques are described in the literature for a specific category, judgment or a hybrid approach was utilized to deem what fit for this study. In line with the expanded view diagram, transportation, lodging, food and beverage, and system infrastructure were all assessed to varying degrees. Similar methods to this LCA were employed later in the Ski to Sea analysis, though the follow-up study employs more rigorous and detailed techniques to build on the initial efforts on the Backroads assessment. The specifics of the methods for this assessment can be seen in the pre-published paper (Tarricone, 2023).

## Results

Given the expectation for different emissions values, visualizing the data revealed the broad range that accompanies which bounds were chosen. The total values are 1.5 tonnes $CO_2e$ when the bounds are that of just what is in Backroads' managerial influence, 3.5 tonnes $CO_2e$ when assessing all factors within the itinerary bounds from pick-up to drop-off, and finally 12.9 tonnes $CO_2e$ when including the guest travel before and after the official trip.

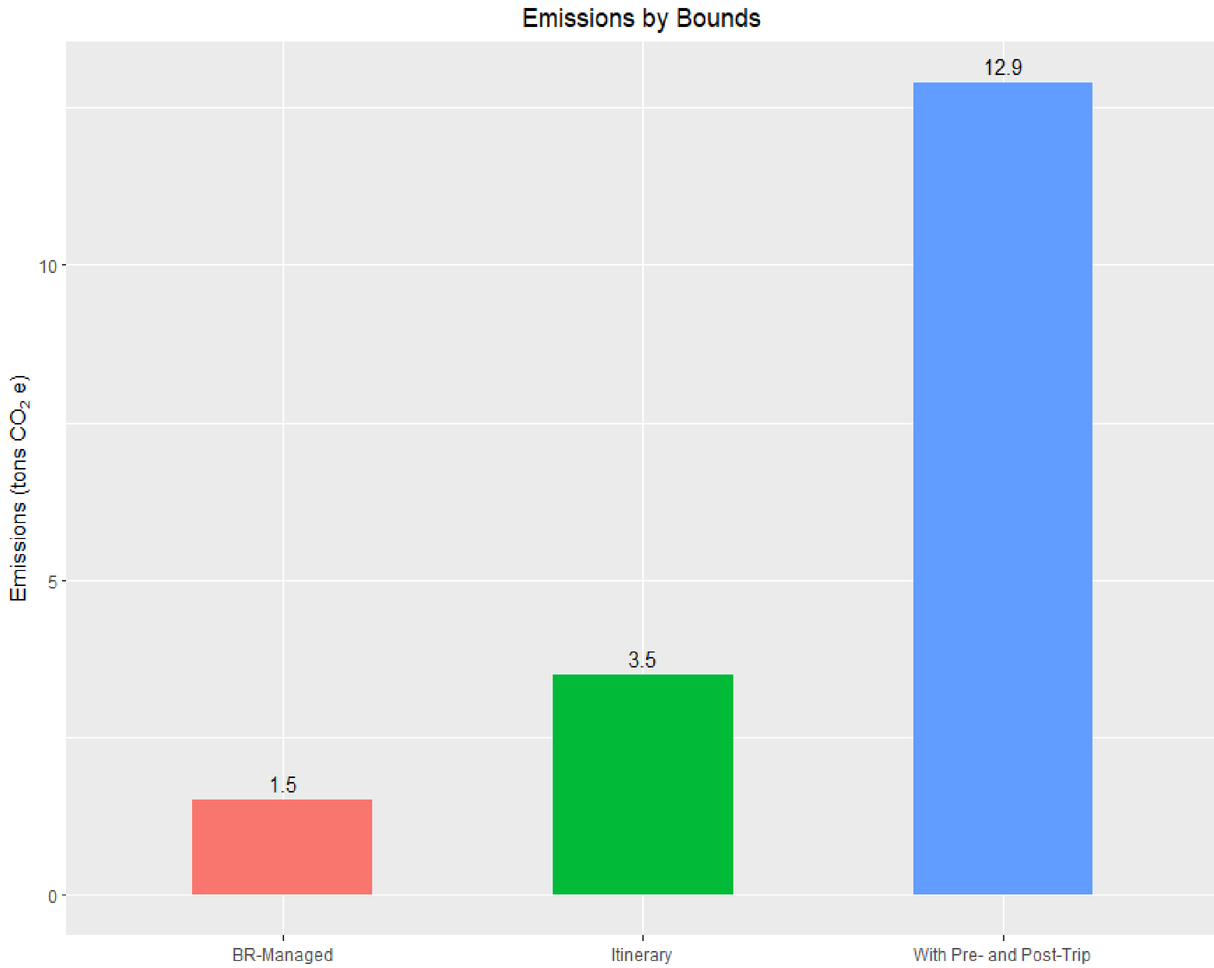


*Figure 6 Backroads trip emissions by case bounds*

To see where the specific differences arise, the values can be assessed based on category, as seen below. It is clear to see that the transportation associated with guest travel prior to and after the trip adds the disproportionate increase over the other options for bounds.

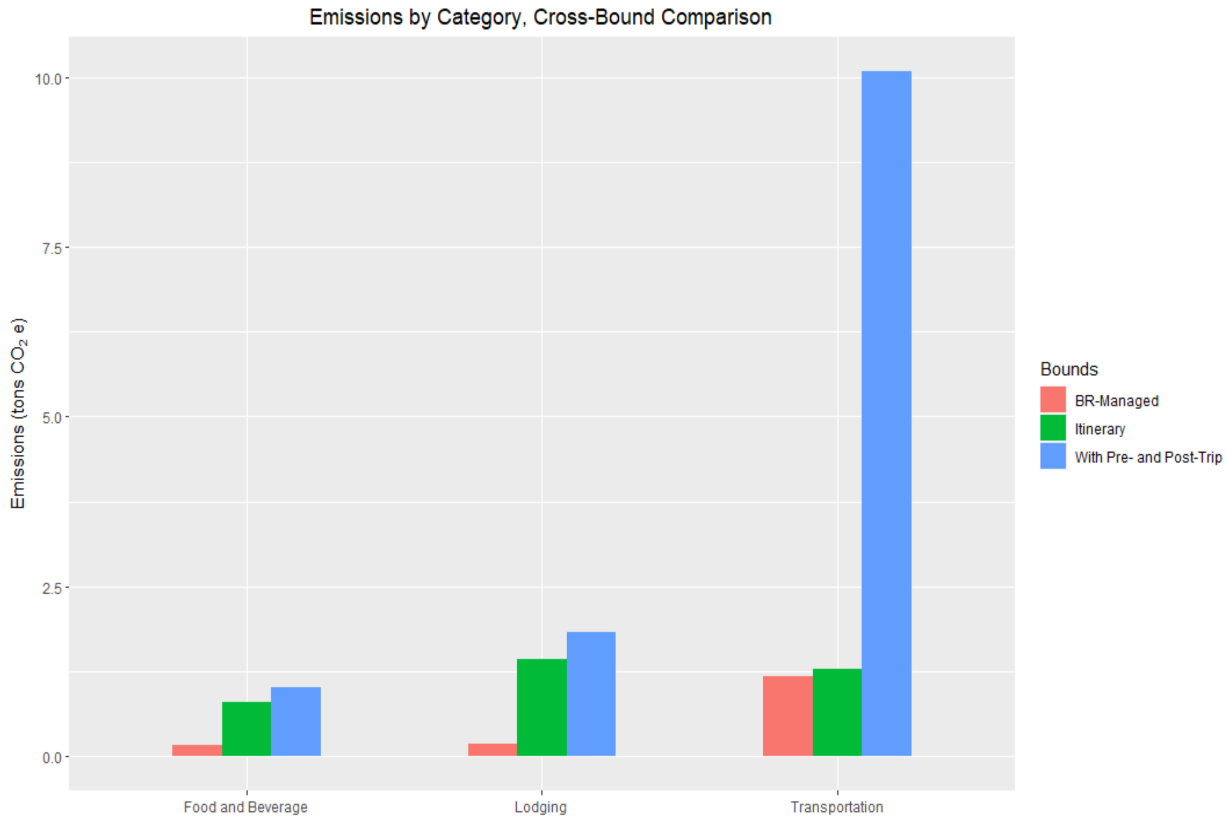


*Figure 7 Backroads trip emissions by category and case bounds*

Thus, including the travel before and after the official itinerary provides a more comprehensive measure of emissions. In addition to what was calculated for the itinerary-bounded case, this would include the flights, two nights of a hotel room (one night on either end of the trip), and two days of food and beverage. Further delineation reveals more detail within this bounded case.

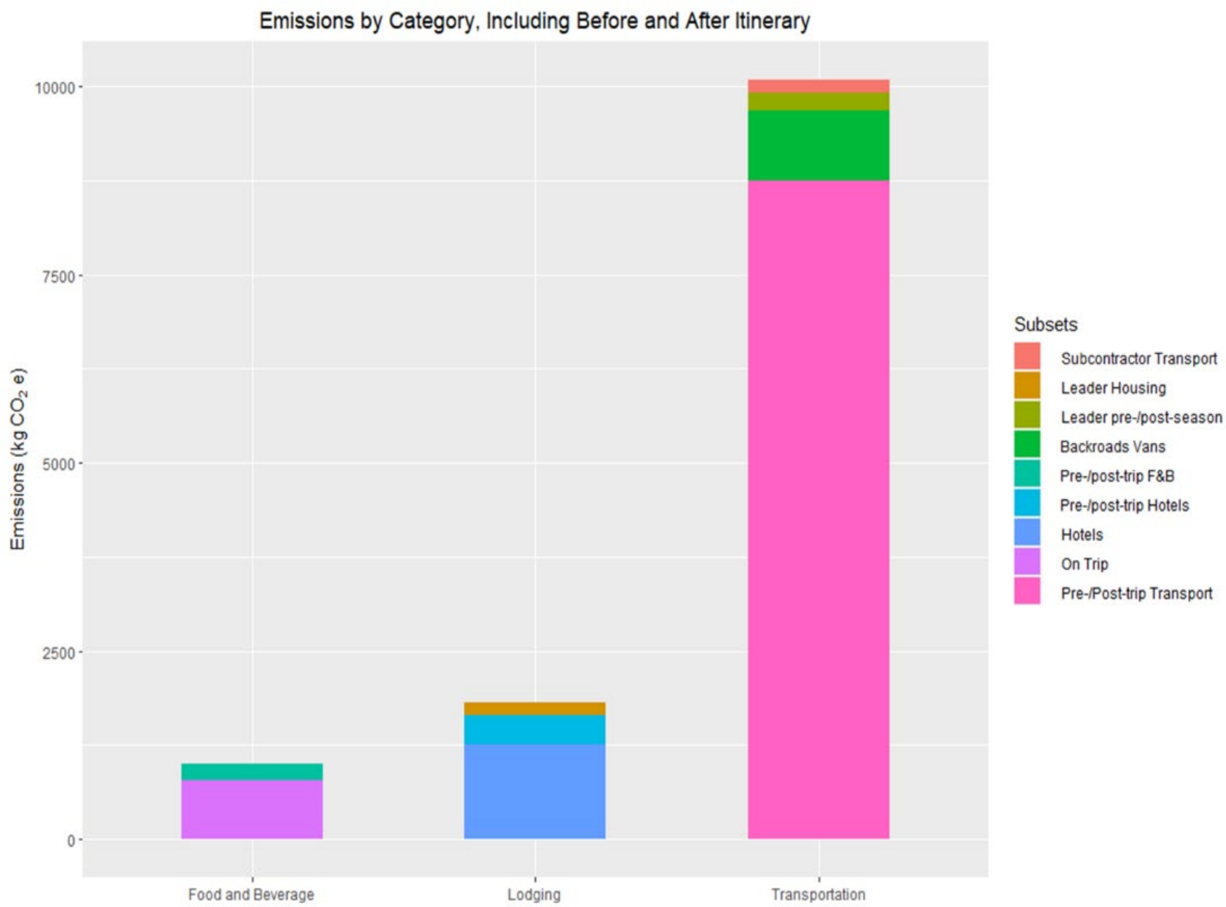


*Figure 8 Backroads trip emissions by category, pre- and post-travel case*

Table 3 relations the values for greenhouse gas emission totals and proportions, while Figure 9 visually represents them in a pie chart.

| Category | Emissions Total (kg $CO_{2e}$) | % Contribution |
|---|---|---|
| Transportation | 10087 | 78.1 |
| Lodging | 1819 | 14.1 |
| Food and Beverage | 1009 | 7.8 |
| **Total** | **12915** | |

*Table 3 Backroads trip emissions, pre- and post-trip transportation case*

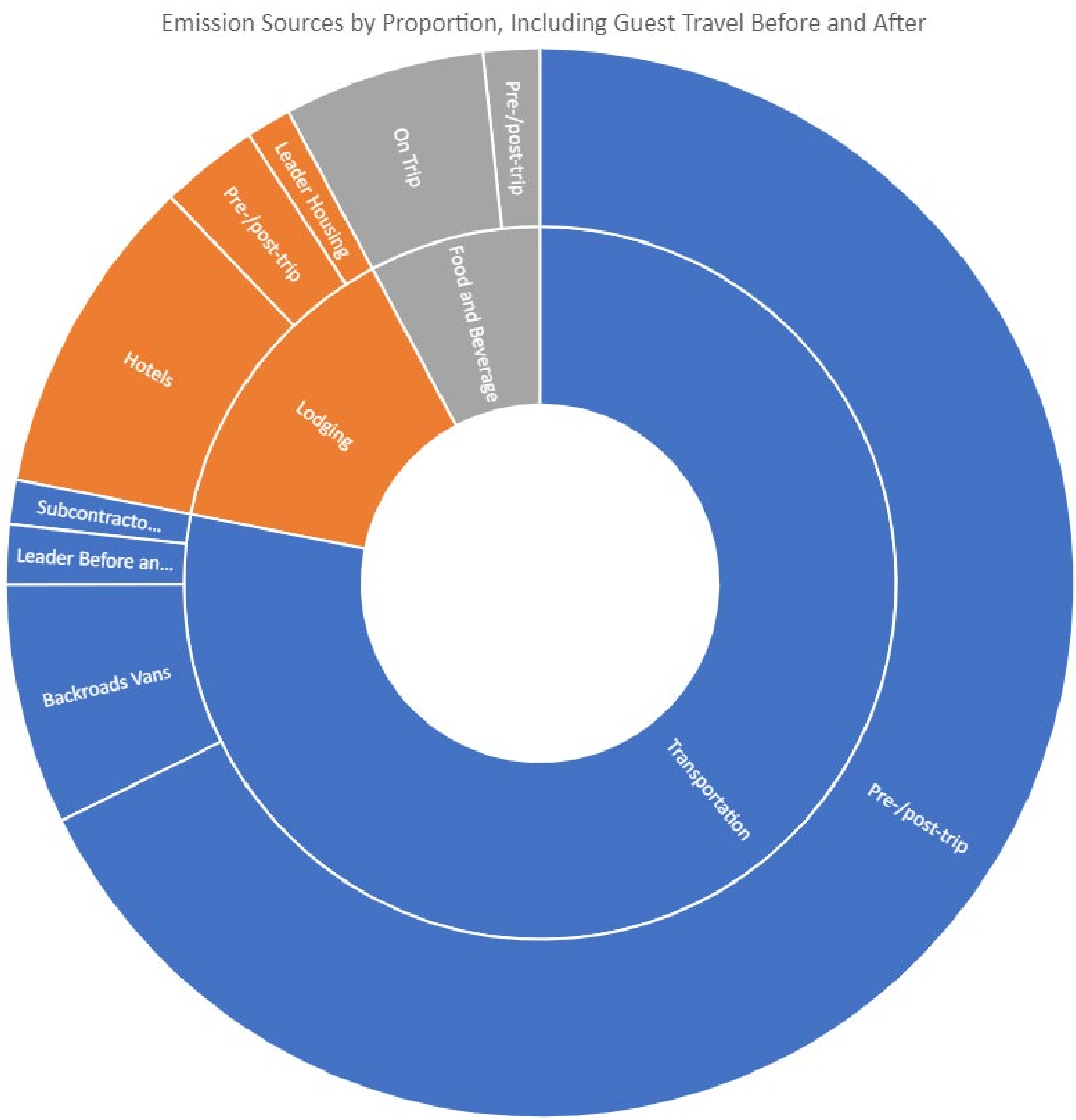


*Figure 9 Backroads trip emissions by category, proportional representation*

Transportation accounts for 78.1% of the trip's emissions, held primarily in the travel to and from the itinerary bounds. Lodging then accounts for a much smaller proportion at 14.1%, with food and beverage rounding out the categories at 7.8%.

**Main Takeaways for Further Studies**

Assessing Backroads' biking trip from Bozeman, MT to Jackson, WY provided a scalable framework which could be used as a tool for subsequent studies. By gaining insight into emission origins and magnitudes, priorities in further studies in the ecotourism realm were identified. A chief takeaway is in the magnitude of impact that bounds have in calculated greenhouse gas emissions, signaling the necessity for proper pre-emptive determinations. Though the Backroads-managed and trip itinerary-bounded cases revealed interesting conclusions in their own rights, the inclusion of travel prior to and after a trip is necessary for a comprehensive analysis. Additionally, this preliminary study revealed the variety of trip types, locations, and activities that may all be assessed using LCA. Understanding the broad motivations with an appropriate level of nuance can help in furthering adoption and implementation of LCA in ecotourism with corresponding management practices.

# Chapter 3: LCA in Events

One under-explored area of ecotourism is in nature-based events, a subcategory which could benefit from a framework of LCA-based management and decision-making. Depending on the context, events can be represented by varying numbers of people following a similar tourism itinerary, though the number of assumptions will likely scale with the size of the event. Toniolo et al. describe how LCA can be a powerful tool for assessing events to accurately classify and quantify chosen environmental impacts (2017). Such results can then be used to inform organizers and influence management for the future. For example, Newland et al. classifies trail racing events in the national parks as such in a sustainability analysis of the category (2021).

Events present powerful opportunities to influence positive environmental and social changes. Their localized nature act as a unique draw for participants and can foster a sense of community for those visiting and local alike (Dolf, 2017; Getz, 2008). This sense of community can act as a fulcrum for social change (Bladen et al., 2018; Dolf, 2017). Events can provide grounds for “liminoid spaces,” which can be used to inspire engagement and emotion (Chalip, 2006; Dolf, 2017). Engaging both participants and residents can thus foster an appreciation for nearby natural spaces, an understanding climatic impacts from participation, and an openness to defined solutions. These messages can be amplified through media past the event’s particular place and time to a wider audience as well (Dolf, 2017).

These catalysts for improvement and change may be outweighed by the impact of the event itself, however. It is argued that with the likes of environmental messaging by FIFA and Formula 1, events held may simply be another form of greenwashing (T. Miller, 2016) Resources and inputs are required for events of any size. Thus, even a positive benefit may not account for the detrimental effects of the event. In analyzing assessments that have been conducted on events, it has been found that the true impacts are many times underreported or underestimated, oftentimes revealing a need for improved methods (Dolf, 2017; Getz, 2009). One such example can be found with the 2016 Olympic Games golf course in Rio de Janeiro. A claim that sustainability measures were included was overshadowed by a subsequent study that revealed a far larger negative environmental impact than projected. Short planning cycles that lead to insufficient prior assessment is cited as one explanation for such shortcomings in LCAs, which then limit reasonable insights to be drawn from them (Dolf, 2017; Gaffney, 2013). To help combat this, more standards have been developed specifically to suit events, such as ISO 20121 Sustainability in Event Management. These standards aim to provide a framework for planning, assessing, and minimizing impacts on the social, economic, and environmental levels (Dolf, 2017; ISO, 2019).

At this stage, large events have been those with the ability to allocate resources and effort into assessing impacts with enlisted sustainability experts. Some pre-eminent studies in this category include assessments done on behalf of FIFA World Cups (Crabb, 2018; Death, 2011; Dolles & Soderman, 2010; Spanos et al., 2022), the Olympic or Paralympic Games (Dolf, 2017; Preuss, 2013; Yuichi, 2020), and the likes of the NCAA March Madness basketball tournament (Cooper & McCullough, 2021). However, studies aren't limited to events of such a scale. Events of a smaller nature have been studied, including the University of Arizona's homecoming football game (Edwards et al., 2016), a University of British Columbia basketball game (Dolf, 2011), or a single English Premier League soccer match (Sky, n.d.). Finally, event-related LCAs are also conducted with more limited scopes, as with Vercalsteren et al.'s study regarding types of drinking cups used at public events (2010). Though research has been done at a variety of levels, Dolf describes that there is a research gap in small to medium scale events. Although public recognition of so-called “mega” events dwarfs that of smaller ones, “micro” and “small” events constitute most events that take place. One example can be found in the International Tennis Federation’s representation of its sanctioned events, seen in Figure 10 (Dolf, 2017; *ITF*, n.d.). The budgets to the right of the pyramid show the proportions inherent to smaller-scale events. With such a stark concentration in resources and numbers, an LCA framework that can be applied to such events will allow for further application and standardization for expanded use.

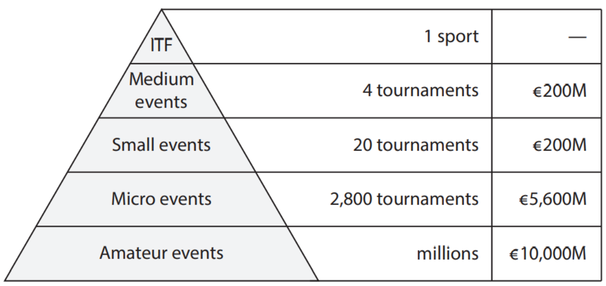


*Figure 10 Number of International Tennis Federation events classified by size and financial levels (ITF, n.d)*

# Ski to Sea LCA

The Ski to Sea race in Bellingham, WA is one such small-scale, ecotourism event. This 90-mile, seven-leg relay race begins near the base of Mt. Baker and weaves its way through diverse ecosystems and communities by different modes to finish in Bellingham Bay. Three to eight team members utilize cross country skis, downhill skis/snowboards, running, road bikes, canoes, cyclocross bikes, and sea kayaks during this shared journey. It is the largest one-day event in Whatcom County and Bellingham each year (Ski to Sea, n.d.). With nature as the arena for participation, a relatively small size (n=3894 participants in 2023), and a participant group that hails from as far as thousands of miles away, Ski to Sea can combine elements of LCA from both the tourism and event subspecialties.

Revisiting Fennell's definition of ecotourism can reveal a number of elements that support classifying Ski to Sea as such: "natural resource-based tourism" with a primary focus on experiencing nature, with management goals to be "low-impact, non-consumptive, and locally oriented" (2020). Baker-Snoqualmie National Forest frames the first few legs, the Nooksack River is prominently used, and Bellingham Bay concludes the race. The varied natural environment and scenery have been foundational for this race for half a century. Race organizers have recognized this and have begun to take steps to assess and respond to environmental concerns. Ski to Sea organizers have partnered with Sustainable Connections, a Bellingham-based sustainability advocacy group, to reduce impact through the Toward Zero Waste program. Put on by a local non-profit organization with a team of over 1000 volunteers, steered by a race committee of over thirty community members, and responsible for charitable donations of over $133,000 to local beneficiaries, Ski to Sea is locally oriented its mission.

This LCA is intended to quantify and characterize emissions to provide a foundation for decision-making and management in subsequent races. Since Ski to Sea is highly contingent upon the quality of surrounding nature, there is a vested interest in maintaining the ecosystems that facilitate the race long term. Only through understanding and accounting for emissions can these impacts begin to be addressed. Empirical data is necessary to inform decision-making (Dolf, 2017). Additionally, Ski to Sea is part of a suite of events put on by Whatcom Events. The process in this study can have elements adapted to expand the benefits derived not just from LCA, but from the subsequent decision-making process that follows. A more systematic, holistically considerate environmental strategy can be developed over time in the recreational sphere.

## Project Scope and Boundaries

The focus was on the race, its operations, and the choices incurred by racers in connection with their participation (transportation and marginal shifts in lodging and food). Scopes 1 and 2 were predominantly considered, with Scope 3 acknowledged but not applied in all contexts. There are other categories that can be assessed in the future, like impacts on water resources with mass participation on water resources, parking runoff, eutrophication or acidification potential, or waste.

## Functional Unit

The functional unit for this study was a typical Ski to Sea participant, who travels to and from their origin and partakes in the race. With a total of 3,894 participants, racers could exhibit a large range of emissions based on transport, lodging, and food options. Emission values were thus aggregated across categories, which reasonably approximated impact that could be attributed to any one individual.

## Indicators Studied

As with the Backroads case study, the indicator of focus is climate impact, as measured by $CO_2e$ emissions.

## Expanded View Diagram

The preliminary work done with the Backroads study provided a foundation by which an expanded view diagram could be developed specifically for Ski to Sea.

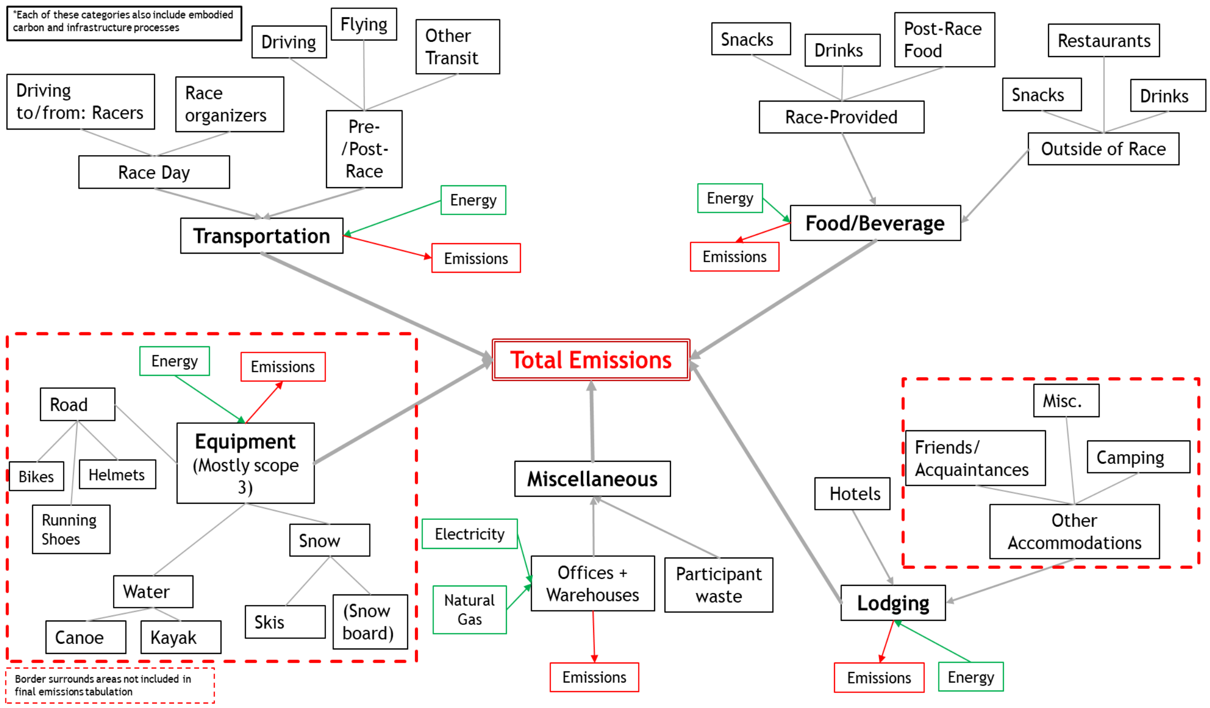


*Figure 11 Expanded view diagram for Ski to Sea*

# Methods:

Given the variety of emission sources associated with an event like Ski to Sea, an array of techniques for reasonable approximation were emulated from studies that focused on each individually or in some combination. Where multiple techniques are described in the literature for a specific category, judgment was employed in choosing the most appropriate individual or hybrid approach for this case and described accordingly.

## Transportation:

In past LCA studies that focus on travel and location-based events, a majority of energy and emissions are associated with transportation (Death, 2011; Dolf, 2011; Edwards et al., 2016; Kitamura et al., 2020; Sharp et al., 2016). This study aims to combine methods from previous studies and supplement with further details to garner a comprehensive understanding of Ski to Sea's transportation impacts. The two main categories considered in this assessment are participant transportation (both to and from Bellingham and on race day) and operational transportation (equipment, volunteers, and other organizing efforts). Given this category's outsized impacts, priority was given to identifying and accounting for the nuance that exists in this multi-modal, international case.

**Transportation Survey**

Procedures in line with previous studies are augmented at points by incorporating survey data to add accuracy to approximations made within this category. This survey was sent out to all participants who did not list Bellingham, WA as their home address. Questions covered topics including racer departure location, carpooling rates, flight travel paths, and rates of equipment hauling, with n=401 respondents. Given the total group size (n=3894), a survey with a 5% margin of error at a confidence level of 95% would require 350 respondents. Thus, the sample size for this survey allows for reasonable confidence in applying survey results to the race population. The questions posed can be seen specifically below, while a copy of the full survey can be accessed in the appendix.

1. From what city, state, and ZIP will you be traveling?
2. How will you be traveling to and from Bellingham?
3. If you plan on driving, with how many other team members will you *likely* be carpooling?
4. If driving, do you plan on driving with a canoe, kayak, bike, or roof box on top of your vehicle?
5. If you are flying to the event, into which city will you be flying?
6. What is your flight path? (ie Indianapolis to Seattle direct, Chicago to Bellingham via Seattle, etc)
7. If flying into another city, how do you plan on getting to Bellingham for race day?

8. Optional but helpful: What is the name of the team with which you'll be racing?

Initially, raw data for race participants was geocoded, utilizing zip codes to provide coordinate values through the Geocodio data service. With the latitude and longitude data available, distance measures could be assessed. For an initial estimate, the Haversine formula, that which relates straight-line distance on the surface of a sphere, was used to find respective distances between the participant origin location and Bellingham (set with the coordinates of 48.7519, -122.4487). This distance provided a reasonable proxy for distance at this initial stage, commonly used in spatial research:

*Miles =ACOS(COS(RADIANS(90-Lat1)) * COS(RADIANS(90-Lat2)) + SIN(RADIANS(90-Lat1)) * SIN(RADIANS(90-Lat2)) * COS(RADIANS(Long1-Long2))) * 3959* (Geocodio, n.d.).

These distances were arranged and compared among the groups based on responded travel modes (personal vehicles, n=331; plane, n=56; other, n=4). Generally, these provided an assumptive basis for classifying raw racer data. For the four instances of "other", two journeys were defined by ferry travel, one by train, and one by sailboat. Given the minimal contribution of other modes within the survey (~1%) and that their modes still have a degree of emissions, considering the data solely with respect to personal vehicle and plane travel was assumed for the participant population.

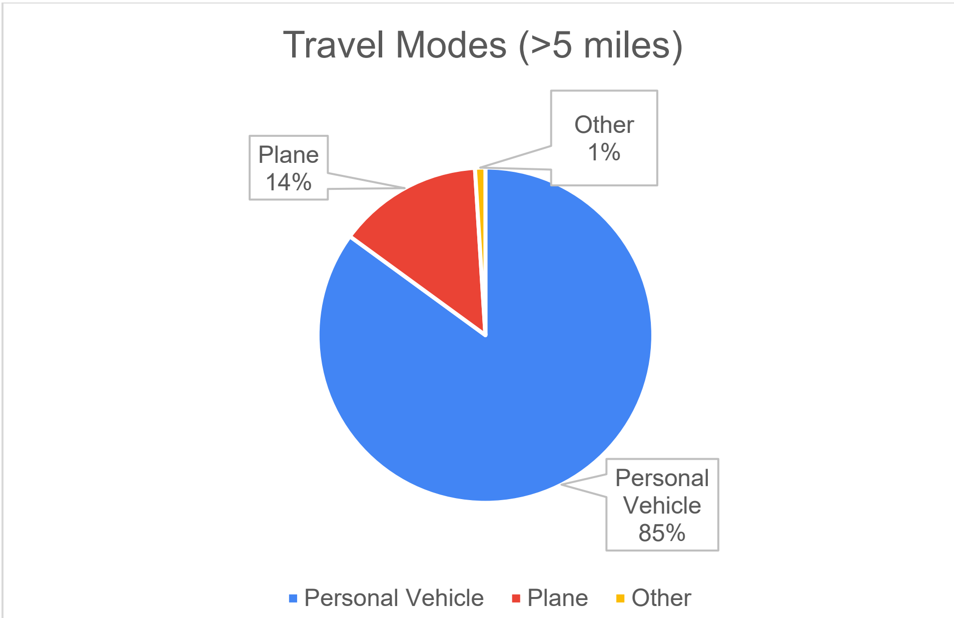


*Figure 12 Travel mode proportions, origins >5 miles away*

*Transportation Survey: Mode by Distance Approximation*

The survey allowed for identifying the relationship between distance and whether a personal vehicle or plane is used. Below, a boxplot shows the general relationship with unsurprising characteristics. Personal vehicles were used far more frequently at lower distances than planes, though there is an area of significant overlap between the farthest car leg (954 miles) and nearest plane leg (373 miles).

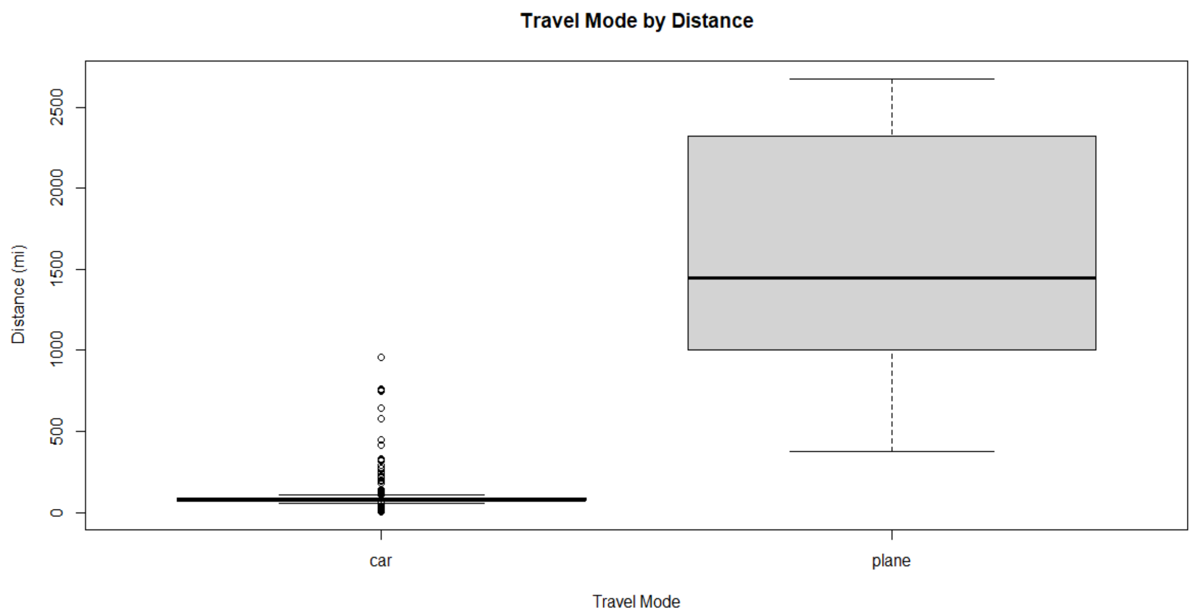


*Figure 13 Comparison of personal vehicle to plane by distance*

Two melded groups were considered within the bounds set by the farthest driver and closest flyer from the survey. The resulting 600-mile range was divided into two groups, as it was assumed the rates of flying and driving would vary within it. The groups 370-670 miles and 671-970 miles away and their respective modal proportions can be seen in Table 4. These proportions were then logged for use in the final emissions data tallying.

| Melded Rates by Mode | | | |
|---|---|---|---|
| | **Distance** | **Count** | **Percentage** |
| Personal Vehicle | 370-670 | 9 | 90% |
| Plane | 370-670 | 1 | 10% |
| Personal Vehicle | 671-970 | 6 | 60% |
| Plane | 671-970 | 4 | 40% |

*Table 4 Melded rates by distance and mode*

*Transportation Survey: Carpool Rates by Distance*

For personal vehicles, the survey data of interest was utilized to find carpool rates and those rates with respect to distance from Bellingham. These rates were determined by isolating all survey participants' entries that indicated a personal vehicle would be the main mode of transportation, with a particular focus on distance and number of carpoolers ("0" representing just the driver and up to "5+", which would indicate 6 or more people in the vehicle). For the sake of analysis, any "5+" entries were assumed to be 6 unless otherwise stated. For instances in which multiple submissions had a shared team name, the same number of carpoolers, and the same origin, repeats were deleted to avoid double counting in these respective categories.

An initial line of questioning aimed to understand whether distance from Bellingham impacted carpooling rates. First, a cumulative number of vehicles as a function of distance and the cumulative number of vehicles with carpool size, $s_i$, as a function of distance were found. This provided the basic insight for understanding any major trends that existed between these factors. Trends past what is shown in the following figure did not appreciably change, so it is presented to show detail in the distance range.

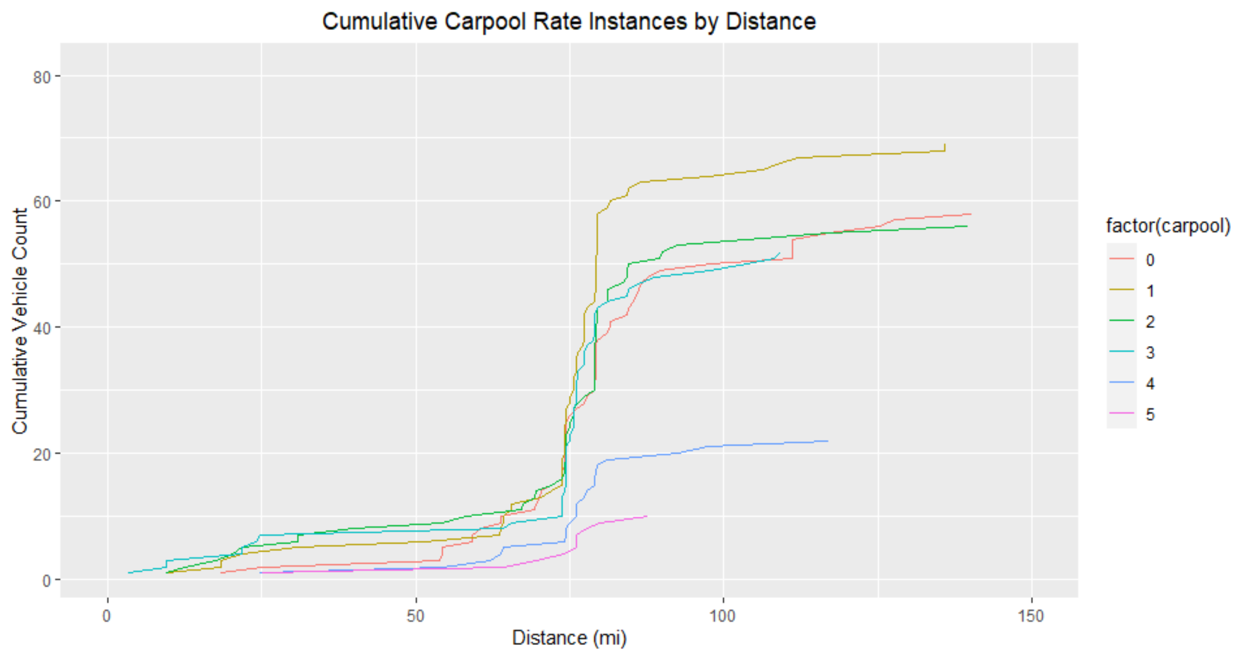


*Figure 14 Cumulative carpool rate instances by distance*

This visualization demonstrates that the major changes occurring in relative proportions of carpooling are happening between 50 and 100 miles. This likely reflects the prevalence of vehicles traveling to the event from the greater Seattle area. Using this as a guide, these areas were grouped into three bins: bin 1 (0-50 miles), bin 2 (51-100 miles), and bin 3 (>100 miles). The next step was to determine whether these bins had a statistically significant difference in carpool rate means. A simple boxplot shows initial results.

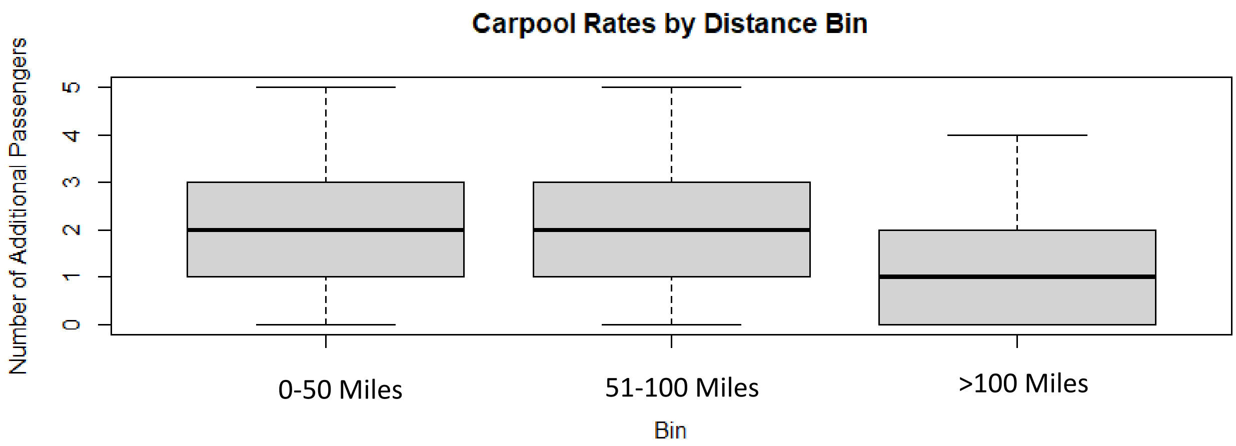


*Figure 15 Carpool Rates by Distance Bin*

Given that each bin had a different number of data points, the respective proportions of carpool rates was found for each, and this transformed data was used for the statistical analysis. To assess normality, each bin's carpool rates and proportional amounts were graphed. Visually, none seem to deviate markedly from normality.

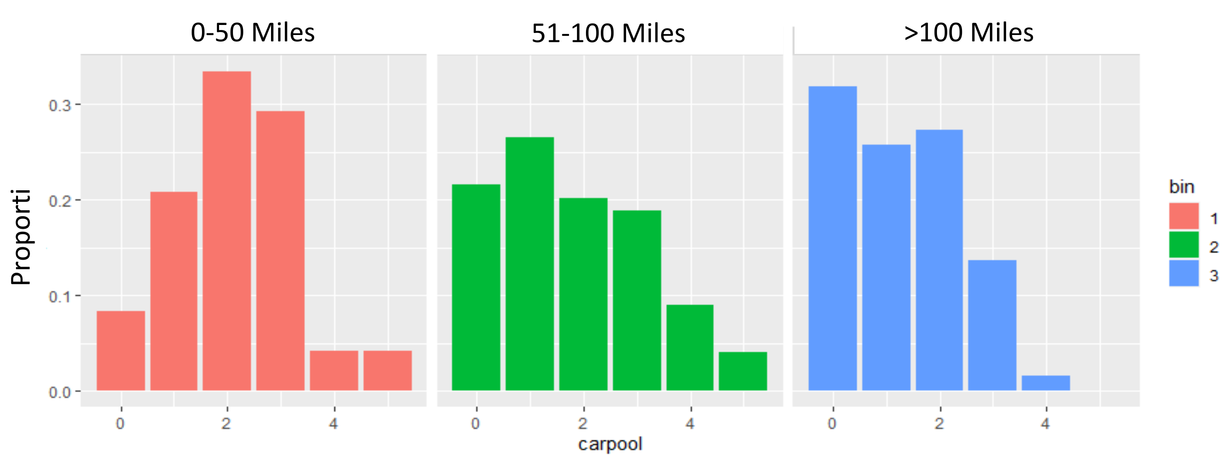


*Figure 16 Proportional distribution of carpool rate responses based on distance bin*

A Shapiro's Wilk's normality test was applied to each, in which the null hypothesis for each asserts that the data are normal. Each p value was >0.05, indicating that the null could not be rejected and that normality is assumed. To test for homoscedasticity, Levene's Test was applied for the dataset, with a null hypothesis that states that the variance among each group is equal. With a p value of 0.209, there is a failure to reject the null hypothesis, where α=0.05, and equal variance is assumed. With these fundamental assumptions cleared, null hypothesis significance testing was completed with an ANOVA to compare the means among these three samples, where α=0.05. A highly significant difference was found (F(2,310)=5.104, p=0.007). The null hypothesis for equal means was thus rejected, supporting the alternative hypothesis that at least one bin mean differed from the others.

To shed light on the specifics, a Tukey HSD test was performed. Results show that bins 1 and 2 did not significantly differ (p=0.48), while bin 3 is significantly different from both 1 and 2 (p=0.02 for each pairwise comparison). There is evidence to support that the means of carpool ridership in bins 1 and 2 can be grouped together, for a weighted mean of 1.82 additional passengers to the driver. Bin 3's mean comes to 1.27 additional passengers to the driver. These values will be applied on a distance basis as a factor for passenger miles in the transportation methods to follow later in the analysis. For racer entries between 0 and 100 miles, the passenger miles computed will thus be divided by 2.82, as that represents the *total* number of people in the vehicle. Likewise, participant passenger miles in for those originating by personal vehicle over 100 miles away will have their mileage divided by 2.27.

| Carpool Bin Statistical Analysis | | | | | |
|---|---|---|---|---|---|
| | **Mean (Additional passengers)** | **Shapiro-Wilk's ($H_0$: Data are normal)** | **Levene's Test ($H_0$: Variance is Equal)** | **ANOVA** | **Tukey HSD** |
| **Bin 1** | 2.13 | p=0.213 | p=0.209 | F(2,310)=5.104, p=0.007 | 1-2 p=0.48, 1-3 p=0.02 |
| **Bin 2** | 1.79 | p=0.491 | | | 2-3 p=0.02 |
| **Bin 3** | 1.27 | p=0.263 | | | Statistically dissimilar to both 1 and 3 |

*Table 5 Statistical analysis for carpool rates by distance*

*Transportation Survey: Equipment Factor*

Survey data was also used to determine the rate at which those using personal vehicles would be hauling equipment externally on the drive (including but not limited to a canoe, a kayak, bikes, or a roof box). A total of 37% of respondents indicated the intention of bringing such equipment. To determine whether this rate could be applied across the racer population, a chi-squared analysis was used to determine whether a relationship exists between response and distance traveled. When $\alpha$=0.05, the null hypothesis that there is no relationship between distance and equipment carrying is failed to be rejected ($\chi^2_{(99,273)} = 118.81$, p=0.09). Thus, this rate could be applied across all personal vehicle use, regardless of origin distance.

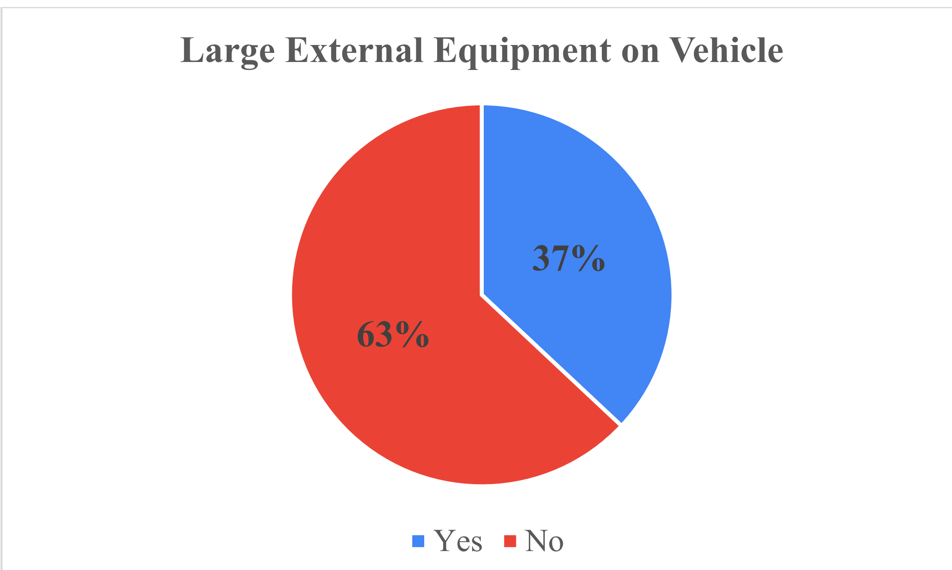


*Figure 17 Rates of large equipment carrying externally for personal vehicles*

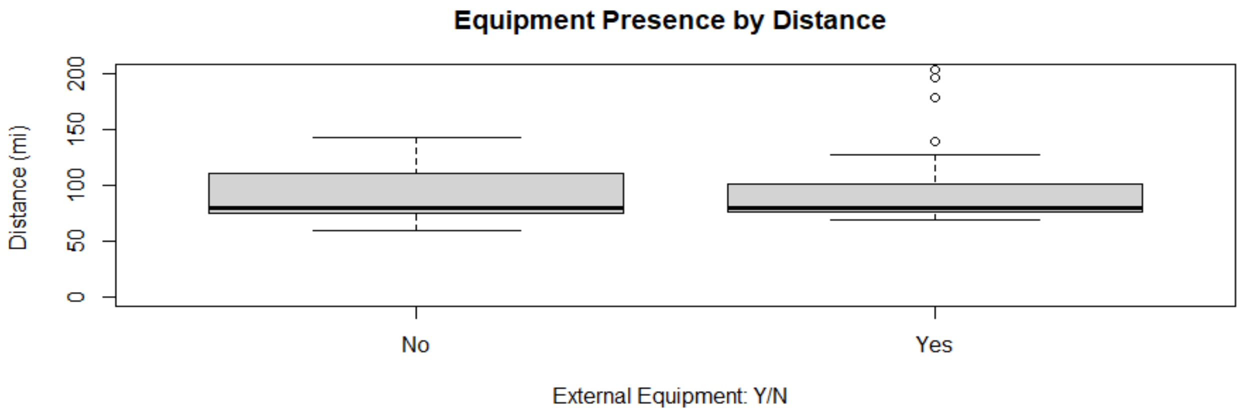


*Figure 18 Transportation Survey: Flight and Bellingham Arrival Paths*

From the survey data, an approximation for proportion of direct vs. indirect flight paths could be calculated. The data indicated that 87.5% of flights were direct (n=49) and 12.5% of flights were indirect (n=7). These figures were applied to the final dataset in approximating the flight emissions as a whole. Additionally, a majority of respondents (n=47, for around 85%) listed an arrival airport other than Bellingham. Understanding this detail provided a basis for establishing the most accurate approach for assessing flight emissions.

| Arrival Airport | Survey Response Count | % | Drive Distance to Bellingham (mi) | Weighted Distance (mi) |
|---|---|---|---|---|
| Seattle (SEA) | 44 | 80.0 | 105 | 87.4 |
| Bellingham (BLI) | 8 | 14.5 | 0 | |
| Everett (PAE) | 2 | 3.6 | 69 | |
| Vancouver (YVR) | 1 | 1.8 | 50.625 | |

*Table 6 Arrival airports summary*

The table above represents the relative proportions of arrival airports and their driving distances to Bellingham. It is clear from this and Figure 18 below that though the Haversine distance to Bellingham was useful to develop modal sorting tools for the final dataset, using Seattle-Tacoma International Airport as the baseline airport for distance approximation will be most accurate. To account for the average distance between these airports and Bellingham, a weighted distance was calculated by multiplying respective airport distances by their relative percentages, then finding the collective sum.

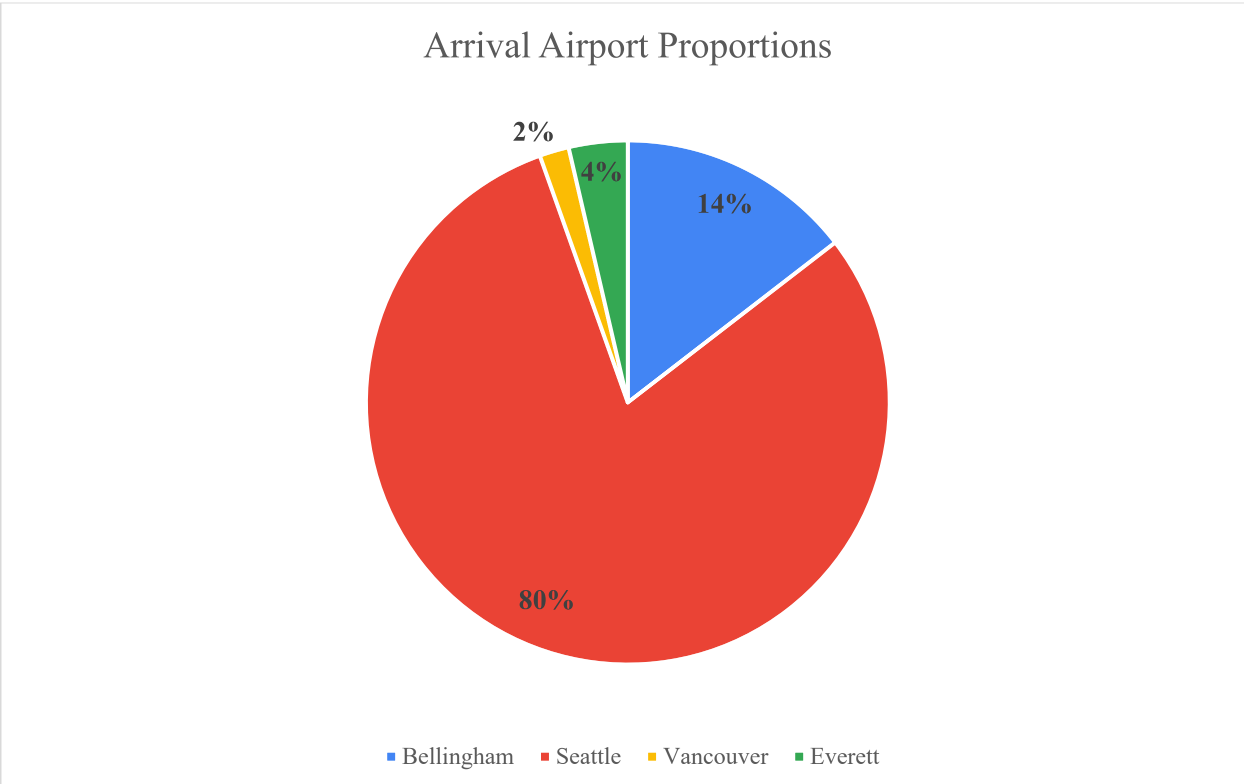


*Figure 19 Proportions of arrival airports*

For those flying into airports other than Bellingham, responses were recorded as to their method of transport to Bellingham from their arrival airport. These were assessed to find the carbon intensity factor to apply to the weighted distance previously found. For both friend and family pick-up and car rental cases, it is assumed that those legs are done solely on behalf of the flying individual. The national average of cars, as reported by the Alternative Fuels Data Center at 24.2 mpg (n.d.), was used in combination with the carbon intensity of gasoline, 8.78 kg $CO_2$ per gallon (*U.S. EIA - Independent Statistics and Analysis*, n.d.). For the bus, emissions rates for buses during peak conditions was used, set at 0.0592 kg/mi (Chester & Horvath, 2009). This rate can be applied to an assumed round-trip journey between Bellingham and the "average" arrival airport, where a 61.2 kg $CO_2$e premium will be applied to all flight cases.

| Mode | Survey Count | % | Carbon Intensity | Weight Carbon Intensity | Average Additional Emissions/Flight (RT) |
|---|---|---|---|---|---|
| Friend/Family | 27 | 65.9 | 0.36 kg/mi | **0.35 kg/mi** | **61.2 kg $CO_2$e** |
| Car Rental | 12 | 29.3 | | | |
| Bus/Shuttle | 2 | 4.9 | 0.0592 kg/mi | | |

*Table 7 Transportation mode analysis, arrival airports to Bellingham*

A summary of the transport survey methods can be summarized in the following figure.

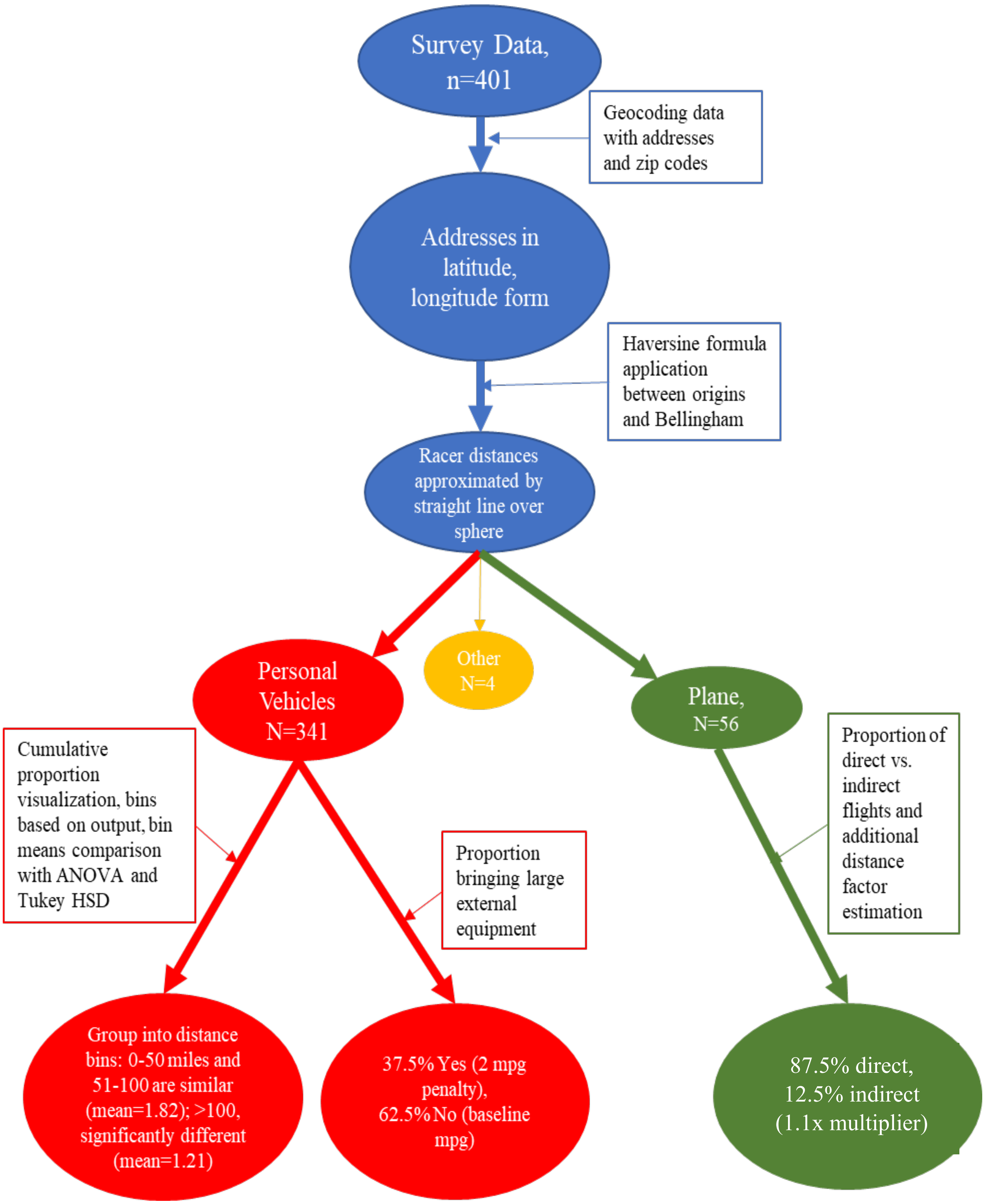


*Figure 20 Flow chart that describes pathways for survey-derived assumptions*

## To and From Bellingham, WA, Entire Participant List

*Groupings for Racer Population*

An initial step for assessing the entire dataset of racers involved determining the travel mode groupings for each (personal vehicle, plane, or Melded 1 or 2). By combining the same techniques used in the survey analysis with some of the survey's chief findings, groups based on travel mode could be approximated from the raw data. These groups could then be individually assessed with the factors devised previously to best approximate total emissions for each participant.

To begin, any locations within five miles of the Bellingham coordinates were not included in this subcategory and were instead assumed to have mileage associated with race day transport based on assumed proximity to the race locale. All remaining entries were then geocoded using the Geocodio web service from ZIP codes to latitude and longitude coordinates, with which the Haversine distances could be computed from the origin to Bellingham. Sorting by mode of travel was the next step. All distances less than or equal to 370 miles were assumed to be in personal vehicles, based on the minimum distance flown represented in the survey. Any racers with a distance of more than 970 miles were assumed to be flying. For the 370-970 mile range, the two melded rates were utilized, as established in the survey section. Melded 1 assumed 90% personal vehicle use with 10% flying for origins between 370 and 670 miles away. Melded 2 assumed 60% flying and 40% driving for origins between 670 and 970 miles away. With these groups established, each could be assessed for emissions.

*To and From Bellingham, WA: Personal Vehicles*

To connect distance and modes with emissions, further refinement took place to ensure accuracy. For all racers within the personal vehicle or melded groupings, a different distance measure was also assessed. In distance measurement, imprecisions can exist between a calculated distance and reality. Boscoe et al. found that a straight-line (Euclidean) approximation is an accurate proxy for driving distance, so long as detour index factor of 1.4 is used (2012). Given that the calculated Haversine distance is calculated as a straight line on the surface of a sphere, this detour index factor would not be directly applicable here. Though these original Haversine distances can be applied for all participants classified as flying, calculating distance by road travel was elected as the most accurate option to represent personal vehicle miles.

Utilizing the GoogleMaps API in RStudio, a pairwise matrix of distances between the origins (n=3548) and Bellingham was utilized. In every case, this increased the travel distance to a degree, more accurately reflecting the true miles a vehicle would travel overland to arrive in Bellingham. A copy of this code can be found in the appendix.

From here, individual emission contributions were calculated per individual. Total gasoline volume (gal) was estimated using 24.2 mpg (*Alternative Fuels Data Center*, n.d.), which was used to calculate total drive emissions, assuming 8.78 kg $CO_2$ per gallon (*U.S. Energy Information Administration - EIA - Independent Statistics and Analysis*, n.d.). These emission values were then doubled to account for a round-trip journey.

*To and From Bellingham, WA: Flights*

As demonstrated in the survey analysis, using Bellingham as the predominant arrival airport would likely decrease accuracy. Given that 80% of survey respondents who planned to fly chose Seattle (SEA) as their destination airport, this was chosen as the baseline for flight distances. A new Haversine distance measure was computed for each racer within the flight group, set between the respective origins and Seattle. This provided a baseline mileage upon which the carbon intensity of flying, 157 grams $CO_2e$ per mile, could be applied (Graver, 2013) At this stage, these baseline emissions reflected all direct flights.

From here, the 12.5% indirect flight rate could be integrated. On average, an indirect flight route will emit approximately 10% more than its direct corollary (Baumeister, 2017; Debbage & Debbage, 2019). Thus, a weighted proportion was taken to reflect these rates. Each emission total was multiplied by .875 to reflect the rate of direct flights, and it was added to the product of the same emission total's product with .125 (to reflect the rate of indirect flights) and 1.1 (to reflect the GHG emissions premium). This allows for this factor to be considered in the total without knowing the specifics of every assumed flight path.

Finally, to best incorporate the "average" ground travel that accompanies flying for the event, the value of 61.2 kg $CO_2e$ was added to this adjusted total. The resulting total reflects the combination of these various considerations. Other factors that would certainly impact this include actual flight trends, the need for connecting flights, and the impact of possibly flying business class instead of economy (Sharp et al., 2016). However, these attributes were not quantitatively considered in the course of this study.

*To and From Bellingham, WA: Melded Rates*

A combination of methods was used to approximate the emissions associated with the established melded rates. For any participant with an origin that incurred a designation of Melded 1 or 2 (between 370 and 970 miles away), both driving and flying emissions estimates were calculated as previously described. From here, the simple proportions derived from the survey data were then applied. For the Melded 1 group (370 to 670 miles), a weighted proportion combined 90% of the driving emissions with 10% of the flight emissions. For the Melded 2 group (>670 to 970 miles), a similar process combined 60% of the driving emissions with 40% of the flight emissions.

A flow chart of the transportation process of the roundtrip journeys between the origins and Bellingham can be seen in Figure 20.


*Figure 21 Flow chart for calculating total distance emissions*

**Operational Transportation**

To facilitate the race, Ski to Sea has a team of one FTE Race Director, a seasonal part-time Operations Manager, and a volunteer/equipment coordinator. This team, along with volunteers, is responsible for race set-up. A number of different tasks required for the race contribute to greenhouse gas emissions both throughout the year and in immediate temporal proximity to race day. In broad terms, race set-up and tear down, coupled with office utility use, account for the majority of emissions that are not otherwise covered in categories deemed more appropriate (volunteer transport and meals on race day are accounted for in other, respective categories, for instance).

To begin, there was a focus on operational elements that directly related to race day set-up and tear down. Using information from the race director, the systems in place for such tasks were mapped, mileages tabulated respectively, and emissions were calculated with respect to those distances and vehicle type. Included in this assessment were equipment transfers between Bellingham, Lynden, and the race sites, Porta-Potty delivery from Honey Bucket, trash and recycling services through Sanitary Services Company (SSC), and canopy delivery from Pacific Party Canopy.

To assess routes, mileages, vehicle used, fuel type, and schedules, direct interviews with the responsible parties were conducted. This information was then used in conjunction with Google Maps to find the total miles traveled associated with each respective operational element. Combining such distances with fuel intensities and global warming potentials (Table 17) allowed for the approximation of greenhouse gas emissions from each component. Specific routes and their maps can be referenced in the supplemental materials.

**Race Day Transportation**

Given the number of legs of the race along its 90+ mile length, personal automobiles are predominantly used in racer and volunteer transport to and from race sites. Both participant and volunteer transport were considered in their own cases, as the logistics for each group differed. For racers, the assumptive basis for a team's transport strategy uses three cars, as is officially advised by the race organizers. The designated route with respective car segments can be seen below in Table 8. This provided the basis for understanding mileage per team (with the exclusion of the 7 car-free teams).

| | | |
|---|---|---|
| **Vehicle 1** | | |
| City Hall-Heather Meadows | | 56.5 |
| Heather Meadows-City Hall | | 56.5 |
| | Total | 113 |
| **Vehicle 2** | | |
| City Hall-Riverside Park | | 15.6 |
| Riverside-Hovander | | 17.2 |
| Hovander-City Hall | | 10.1 |
| | Total | 42.9 |
| **Vehicle 3** | | |
| City Hall-Zuanitch | | 1.8 |
| Zuanitch-Fairhaven Parking Lot | | 4.7 |
| | Total | 6.5 |
| **Vehicle 4 (Director estimate: 15% of time)** | | |
| City Hall-Salmon Ridge Sno-Park (bike) | | 48.5 |
| Return | | 48.5 |
| | Total | 97 |

*Table 8 Race day participant vehicle plans*

A fuel economy rating of 17.5 mpg was used for this approximation. According to the DOE's Alternative Fuels Data Center, the US national average is 24.2 mpg for passenger cars and 17.5 mpg for light trucks/vans (n.d.). Though race day utilizes a spectrum of vehicles, the lower value was employed for a variety of reasons. First, the nature of these legs require bringing specialized equipment on the exterior of the vehicle. Inclusion of kayaks, canoes, bikes, and cargo boxes increase drag and lower fuel economy by between 2 and 17% (*Fueleconomy.gov*, n.d.). Additional mpg penalties exhibited on race day include extra weight in equipment and passengers (a 1% deduction for each extra 100 lbs) and mountainous terrain (thousands of vertical feet are gained on the Mt. Baker highway that leads to four of the race legs). To handle such requirements, a larger proportion of vehicles is assumed to be of the light duty vehicle category than passenger cars. The combination of such factors led to the assumed value of 17.5 mpg. For volunteers, a similar process was used for a collection of different routes. The defined routes, volunteers required per site, and assumed number of volunteers per vehicle are defined in the corresponding table in the Results section.

Though some electric vehicles are used on race day, their impact on the average was considered to be negligible. The assumed fuel type used was gasoline, with a carbon intensity of 8.78 kg $CO_2$/gallon (*U.S. Energy Information Administration*, n.d.).

## Lodging

After transportation, lodging is recognized as another major contributor to greenhouse gas emissions in the tourism sector (Filimonau et al., 2011). For this event, race participants will generally stay in their homes, homes of family or friends, a hotel, and to a much lesser extent, camping. For those staying in their own homes or in the home of another, the marginal additional emissions were not considered in the scope of this study. Additionally, emissions associated with camping and other fringe cases were assumed negligible based on participant rates and assumed lower impact with the practice. Thus, hotel approximations are considered the chief contributor to lodging emissions. To assess the impacts of hotel stays with respect to this event, the general methods used were as follows:

1. Approximate the total of room·nights attributable to the event.
2. Determine reasonable estimates for energy use in electricity and natural gas per room per night based on prior literature, then find the corresponding carbon intensities for each regionally.
3. Combine these two values to quantify total emissions associated with this category and Ski to Sea.

Specifics for each will be elaborated upon below.

*Approximating Total Room·Nights*

Devising a value for the number of hotel rooms and nights employed was rooted in survey questions attached to and required for each race registration. For respondents who stated they would be using a hotel, a total of room·nights was simply the sum of the stated number of nights from those participants. A further assumption here was for double occupancy for the rooms. Thus, the total room·nights was halved to get a conservative, but likely more accurate, picture of lodging. These methods yield a total of 1808.5 room·nights among racers.

Though not directly racing, one category the survey addressed was in the number of spectators joining. The survey results were filtered to account for racers that had indicated that they would stay in a hotel, tallying those with 3+ visiting spectators. This rate was decided upon as the likeliest maximum a hotel room with two beds would accommodate would be four, so anything more (two racers with an additional 3+ people), would necessitate an extra room. For instances where a racer had 3 or more visitors coming, corresponding room nights were aggregated in total. This approximation added 1334 room·nights, for a total of 3142.5 room·nights in connection to the Ski to Sea event.

| 2023 Lodging Survey Results (Hotel) | | |
|---|---|---|
| # of Nights | # of Responses | Total Room Nights |
| 1 night | 628 | 628 |
| 2 night | 901 | 1802 |
| 3 night | 309 | 927 |
| 4 night | 65 | 260 |
| 5+ night | 0 | 0 |
| | | |
| Total Room Nights | | **3617** |
| Total Room Nights, Double Occupancy Assumed | | **1808.5** |
| Average Nights/Room | | **2.41** |

*Table 9 Lodging survey results 2023*

| Total Room Nights | |
|---|---|
| Room Classification | Room Nights |
| Double Occupancy, Racers | 1808.5 |
| 3+ Visitors in Addition to Racer | 1334 |
| **Total** | **3142.5** |

*Table 10 Total room nights*

*Approximating Nightly Energy Use and Emissions Per Room*

Emissions from energy use in Bellingham, Washington for hotels are primarily related to electricity and natural gas usage. According to the EPA in an analysis on indirect emissions from events and conferences, the amount of energy used by hotels depends on the class of the property (2018). The following figure outlines estimates based on property type. Total energy use in kWh was added for ease of comparison with other studies.

| Room Energy Use Rate (kWh/room·night) | Room Energy Use Rate (mmBTU/room·night) | Total Energy Use in kWh | Room Type | Source |
|---|---|---|---|---|
| 35 | 0.094 | 62.6 | US Upscale | EPA Indirect Emissions from Events and Conferences, 2018 |
| 30 | 0.097 | 58.4 | US Midscale w/ F&B | |
| 19 | 0.059 | 36.3 | US Midscale w/o F&B | |
| 15 | 0.062 | 33.2 | US Economy | |

*Table 11 Hotel room energy rates by room type*

These estimates are in-line with assorted others, which varied among location and hotel type, as outlined below in Table 12 below.

| Room Total Energy Use Rate (kWh/night) | Location | Source |
|---|---|---|
| 25.5 | Poole, UK | Filimonau et al, 2011b |
| 20.9 | Poole, UK | |
| 28 | Italy | Beccali, 2009 |
| 47 | Australia | Lundie et al, 2007 |
| 94 | Australia | Lundie et al, 2007 |
| 41 | Scandinavia | Filimonau et al, 2011b |
| 47 | Scandinavia | |
| **47.2** | **Average Total (kWh/night)** | |

*Table 12 Electricity use per room, various studies*

Since the EPA values in Table 11 vary, composite values for electricity and natural gas use were found based on the official recommended hotel list from Ski to Sea. The majority of hotels were considered midscale with some food and beverage services (hot breakfast), with fewer other options of a higher and lower quality rating. These are outlined below in Table 13. As such, the average from those hotel choices defined the melded rate used, assuming equal rates of stay among them.

| **Ski to Sea Recommended Hotels** | **Type of hotel:** | **Electricity (kWh/room·night)** | **Natural Gas (mmBTU/room·night)** |
|---|---|---|---|
| Oxford Suites | Midscale some F&B | 24.5 | 0.078 |
| Hampton Inn Airport | Midscale some F&B | 24.5 | 0.078 |
| Holiday Inn Airport | Midscale some F&B | 24.5 | 0.078 |
| Holiday Inn Express | Midscale some F&B | 24.5 | 0.078 |
| H2 Suites Hilton | Midscale some F&B | 24.5 | 0.078 |
| SpringHill Suites Bellingham | Midscale some F&B | 24.5 | 0.078 |
| Inn at Lynden | Midscale with F&B | 30 | 0.097 |
| Upscale (locally available) | Hotels and rental homes, etc | 35 | 0.094 |
| Economy (locally available) | Motels, etc | 15 | 0.062 |
| **Average Values** | | **25.2 kWh/room·night** | **0.080 mmBTU/room·night** |

*Table 13 Ski to Sea hotel partners and assumed energy use rates*

*Calculating Total Lodging Emissions*

From here, total lodging emissions were found by multiplying the room·nights by the carbon intensity for the local grid and of natural gas. According to the EPA's eGRID tool, the carbon intensity for Bellingham's grid (NWPP) is 634.6 lbs $CO_2$/MWh, or 0.288 kg $CO_2$/kWh (2021). For natural gas, 56.9 kg of $CO_2$/mmBTU was used (*U.S. Energy Information Administration*, n.d.).

## Food and Beverage

Assessing Food and Beverage emissions involved identifying relevant categories and pursuing each with a suitable strategy. The three sources considered in this study were those from race-day vendors, the increase of food eaten away from home during the course of each participant's trip, and operational food.

*Race-Day Vendors*

For the 2023 race, eight vendors were present. Menus were assessed and interviews conducted with the vendors in order to quantify ingredient amounts, units sold, and fuel consumed throughout preparation and operation for event. Since each of the vendors was present in association with the Ski to Sea event, all emissions embodied in the food and preparation process were considered attributable to the event. Estimates for race day sales were either based on direct interviews or estimates based on averages among the data. OpenLCA software was used to approximate emissions associated with the menu items by the Environmental Footprints (EF) method. Where this source was insufficient, other sources were consulted. Respective values can be seen below in Table 14.

It should be noted that the wood used as fuel is not considered carbon neutral in the course of this study. According to Sterman et al., carbon payback from burning a tree could be 44-104 years in the future, with the possibility that if a habitat shifts from natural forest to plantation, more carbon is introduced overall (Sterman et al., 2018). In a Washington State Department of Natural Resources study, Nichols et al. determine that wood in Washington typically holds from 0.71-0.91 tonnes of carbon for every 100 cubic feet of wood (2020). This provided the basis for converting to 26 kg $CO_2e$/cubic ft by determining total carbon on a per cubic foot basis, then multiplying by the mass ratio of C to $CO_2$ to find the intensity.

| Vendors | Business | On-site Fuel CO2e | Fuel Emissions intensity | Source |
|---|---|---|---|---|
| Vendor 1 | Mt Baker Kettle Corn | 3 gal propane | 5.75 kg $CO_2e$/gal | (EIA - Independent Statistics and Analysis, 2022) |
| Vendor 2 | Crabby's Crab Cakes | 1 gal propane | 5.75 kg $CO_2e$/gal | (EIA - Independent Statistics and Analysis, 2022) |
| Vendor 3 | Gusto Pizza | 3 cubic feet of wood, ~60 lbs | 7.1 kg C per cubic foot of wood; 26 kg $CO_2e$/cubic ft | (Nichols, 2020) |
| Vendor 4 | Feast | ~20 Gal propane | 5.75 kg $CO_2e$/gal | (EIA - Independent Statistics and Analysis, 2022) |
| Vendor 5 | Bay City Ice Cream | n/a | n/a | n/a |
| Vendor 6 | El Agave | ~ 10 Gal Propane | 5.75 kg $CO_2e$/gal | (EIA - Independent Statistics and Analysis, 2022) |
| Vendor 7 | Boundary Bay | n/a | n/a | n/a |
| Vendor 8 | Ovn | 3 cubic feet of wood, ~60 lbs | 7.1 kg C per cubic foot of wood; 26 kg $CO_2e$/cubic ft | (Nichols, 2020) |

*Table 14 Ski to Sea food vendor list with fuel types*

### *Marginal Increase in Food Away from Home*

According to a study by Mackie and Wemhoff, food away from home (FAFH) in the US emits 4.3 kg $CO_2e$/kg food, while food at home (FAH) emits 2.7 kg $CO_2e$/kg food (2020). Thus, there is a marginal increase of 1.6 kg $CO_2e$/kg food for each kg of food eaten away from home than at home. For this study, the goal was to consider what increase in food-related emissions was attributable to the Ski to Sea event. Mackie and Wemhoff estimate that the average person eats 1.63 kg of food per day, 77% of which is food at home and the remaining 23% is food away from home. Given their estimates of emissions for FAH vs. FAFH, this equates to roughly 5 kg $CO_2e$/day (Mackie & Wemhoff, 2020). This is for the average American diet, and it is noted the heavy contribution meat, dairy, and beverages contribute to this amount. Beverages typically compose nearly half of the mass of dietary intake (Heller et al., 2018; Mackie & Wemhoff, 2020).

To not double count the food served on race day, only the day before and after the race are considered in this portion of the analysis. There are many hosted events in Bellingham that encourage FAFH, and many racers take part in these festivities, in addition to FAFH that accompanies general travel. In addition to these specific events, it is worth noting that 14 breweries exist within Bellingham's city limits, as beverages are a top contributor of emissions in the F&B category (Heller et al., 2018). With these things in mind, it was assumed that for those bordering days, the ratio between FAH and FAFH was assumed to be 50% each. Using the same emissions rates, the total for food with these percentages comes to 5.7 kg $CO_2e$/day, a 0.7 kg increase. For the sake of conservative estimate, a dichotomous split was used here. This increase was allocated for a single day for any participant with an origin of up to 100 miles (n=3142), while two days of increased FAFH were attributed to those with a journey over 100 miles to account for travel (n=752) Though imperfect, this method gives some granularity as to how food practices changed for participants during the course of the Ski to Sea weekend.

*Operational Food*

Using data from an interview with the race director, food types and amounts were combined with carbon intensities estimated in the same way as was done with the food vendors.

Foods in these category include meals for volunteers and food included in race packets. A summary of this information can be seen in Table 25.

## Waste

In previous LCA studies for events, waste has typically accounted for less than 1% of the total greenhouse gas emissions (Dolf, 2011; Edwards et al., 2017). In spite of such a small contribution, the category was included for comprehensiveness. To approximate, a general estimate of participant waste amounts was multiplied by an emissions intensity for the category. In line with Dolf's study on small and medium events (2017), a value of around 1 kg of waste stream was attributed per participant for race day. This estimate can be seen as reasonable, as another study showed tourism waste rates of 0.8-1.25 kg per person per day (Mance et al., 2020). Given progress in years' past on reducing event waste, it was assumed that for every kg of waste, one half was recycled or composted. Thus, 0.5 kg of waste was assumed for each race participant.

Dolf outlines the emissions intensity for landfill waste to be roughly 0.57 kg $CO_2e$/kg waste (2017). Multiplying the number of participants (n=3894) by the waste rate of 0.5 kg/day and the emissions intensity of 0.57 kg $CO_2e$/kg waste yielded the total estimate for waste emissions.

## Administrative

One other category to consider is in administration, particularly with energy for office work with respect to the race. Using Google Maps to estimate the office size for Ski to Sea, the area comes to roughly 1267 sq. ft. From here, the carbon intensities per square foot of electricity and natural gas usage were found. The Energy Information Administration estimates that 13.7

kWh of electricity are used for each square foot of a mixed-use office environment (chosen due to the conventional office work done in the space with space for conferencing and some storage) (EIA CBECS, 2018). For the state of Washington, the carbon intensity for electricity averages to 219 lb/MWh, or 0.0995 kg/kWh (*Washington Electricity Profile 2021*, n.d.). For natural gas estimates, the EIA Commercial Buildings Energy Consumption Survey estimates that a mixed-use office space uses 21.8 cubic feet of natural gas per square foot of area (2018).

# Results

Tables and figures of results for each category and subcategory are shown in this section.

## Transportation: Summary

Transportation emissions ranged from under 1 tonne CO2e (<1%) for volunteer transportation to over 230 estimated tonnes $CO_2e$ for transportation before and after (83%). Specific values can be seen in Table 15. Figures 21 and 22 show these values with respect to one another.

| Sub-category | Emissions (kg $CO_2e$) | Relative % |
|---|---|---|
| Transport Pre/Post | 230383 | 83.2 |
| Race Day Transport (Racers) | 42055 | 15.2 |
| Operational Set-up | 3739 | 1.3 |
| Race Day Transport (Volunteers) | 855 | 0.3 |
| **Total** | **277032** | |

*Table 15 Transportation emissions summary*

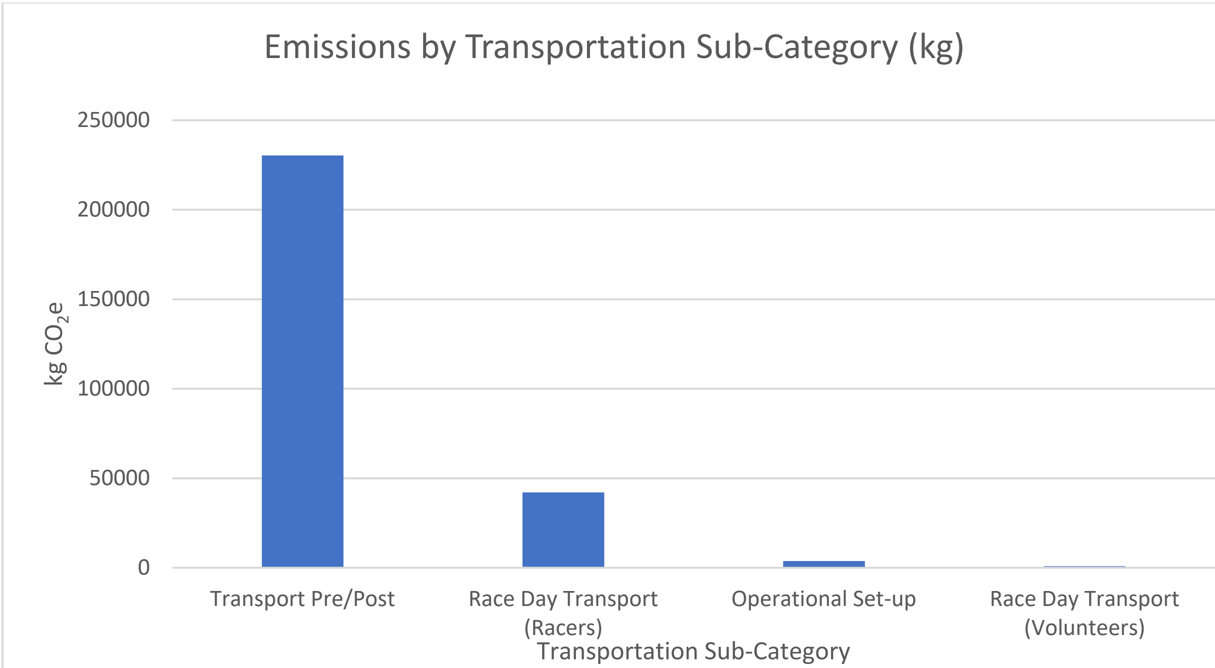


*Figure 22 Transportation emissions by subcategory*

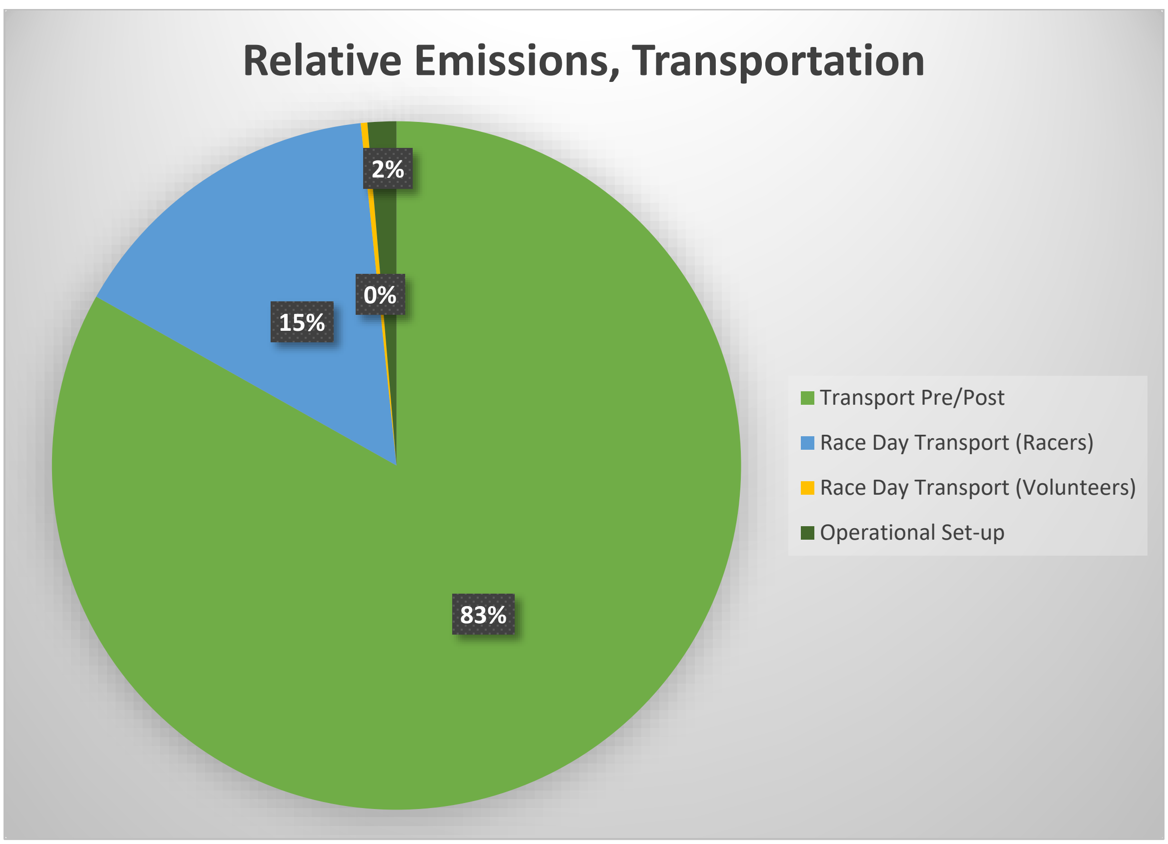


*Figure 23 Transportation emissions proportions*

*Transportation: To and From Bellingham*

Table 16 shows the results for transportation to and from Bellingham. Over 137 tonnes $CO_2e$ were emitted from flying (60%), and the other 40% of travel to Bellingham was accounted for by personal vehicle use with 92 tonnes $CO_2e$ emitted.

| Emissions and Modal Shares and Values Among Racers | | | | |
|---|---|---|---|---|
| **Mode** | **# of Racers** | **Modal %** | **Emissions (kg CO2)** | **Emissions %** |
| Flying | 256.6 | 6.6 | 137290 | 59.8 |
| Driving from >5 miles | 2667.4 | 68.6 | 92270 | 40.2 |
| Live within 5 miles | 956 | 24.6 | Attributed to Race Day Mileage | n/a |

*Table 16 Transportation emissions by mode, to and from Bellingham*

The relationship between the rates of mode usage and corresponding emissions can be seen in Figure 23.

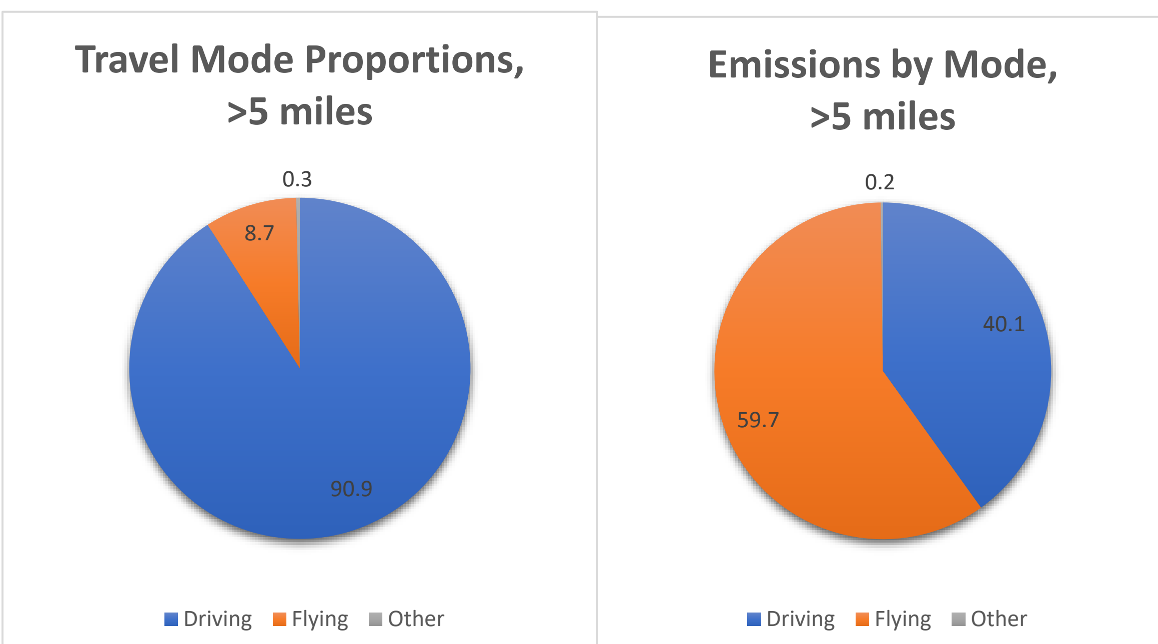


*Figure 24 Comparing travel mode proportions with emissions by mode, origins >5 miles away*

When the results include all transport types, the proportions can be seen in Figure 24.

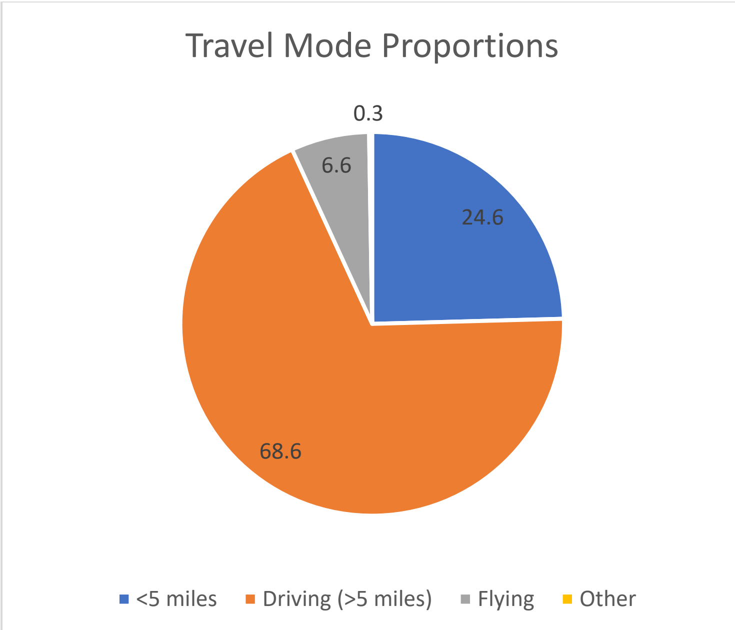


*Figure 25 Event-wide travel mode proportions*

*Transportation: Operations*

Operational transportation calculations and emissions can be seen in Table 17, using information held in Table 18. A total of roughly 3700 kg $CO_2$e were emitted in this subcategory.

| **Emissions** | | | | | |
|---|---|---|---|---|---|
| **Segment** | **Gal** | **CO2 (kg)** | **CH4 (kg)** | **N2O (kg)** | **Total CO2e (kg)** |
| Box Truck | 23.7 | 207.7 | 0.3 | 0.5 | 208.4 |
| GetSimpleBox Big Truck | 121.4 | 1239.1 | 1.4 | 2.6 | 1364.4 |
| Porta-Potty Truck | 153.0 | 1562.5 | 1.8 | 3.2 | 1567.5 |
| SSC | 45.4 | 463.4 | 0.5 | 1.0 | 510.3 |
| Pacific Party Canopy | 10.0 | 88.0 | 0.1 | 0.2 | 88.3 |
| | | | | **Grand Total** | **3738.9** |

*Table 17 Emissions by operational transportation*

| | Fuel intensities | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Fossil Fuel $CO_2$ kg/gal** | **$CO_2$e kg/gal: $CH_4$** | **$CO_2$e kg/gal: $N_2O$** | **Source** | **GWPs** | | **Source** |
| Gas | 8.78 | 0.00038 | 0.00008 | (*Emission Factors for Greenhouse Gas Inventories*, 2011) | 1 | $CO_2$ | (US EPA, 2016) |
| Diesel | 10.21 | 0.00041 | 0.00008 | | 28 | $CH_4$ | |
| Biodiesel | 9.45 | 0.00014 | 0.00001 | | 265 | $N_2O$ | |

*Table 18 Fuel intensities and GWPs for transportation calculations*

*Transportation: Race Day, Racers*

Mileage estimates for two race day driving scenarios are shown in Table 19, using 3-vehicles in 85% of case and 4-vehicles in the remaining 15%, per the race director's estimates. Around 42 tonnes $CO_2$e were found to be emitted here.

| Driving Plan | Miles | MPG | Total Gal | CO2e/Team | | Total $CO_2$ kg (472 Teams) |
|---|---|---|---|---|---|---|
| 3 Vehicles | 162.4 | 17.5 | 9.3 | 81.7 | kg /team | **42,055 kg*** |
| 4 vehicles | 259.4 | | 14.8 | 130.4 | kg /team | ***Based on 85% 3 vehicle, 15% 4 vehicle** |

*Table 19 Race day team travel plan comparison, 3 vs. 4 vehicles*

*Transportation: Race Day, Volunteers*

The number of gallons of gas for volunteer transport is shown in Table 20, with accompanying emissions in Table 21.

| Volunteers | Miles | Number of Volunteers | Volunteers per Vehicle | Vehicle MPG | Total Miles | Total Gallons |
|---|---|---|---|---|---|---|
| Bellingham-Heather Meadows RT | 113 | 26 | 4 | 24.2 | 734.5 | 30.4 |
| Bellingham-Shuksan DOT Shed RT | 95.8 | 27 | 4 | 24.2 | 646.65 | 26.7 |
| Bellingham-Riverside RT | 31.2 | 57 | 4 | 24.2 | 444.6 | 18.4 |
| Bellingham-Hovander RT | 21.2 | 85 | 4 | 24.2 | 450.5 | 18.6 |
| Bellingham Zuanitch RT | 3.6 | 50 | 12 | 24.2 | 15 | 0.6 |
| Bellingham--Fairhaven RT | 7.2 | 95 | 12 | 24.2 | 57 | 2.4 |
| | | | | | **Total** | **97.0** |

*Table 20 Volunteer transportation emissions*

*Combined Race Day Transportation*

Just under 43 tonnes $CO_2e$ were emitted for race day transportation, with less than 1 tonne emitted in connection with the volunteer transport.

| Race Day Vehicle Emissions | | | | | |
|---|---|---|---|---|---|
| | Gal gas | $CO_2e$ Emissions: $CO_2$ | $CO_2e$ Emissions: $CH_4$ | $CO_2e$ Emissions: $N_2O$ | Total kg CO2e |
| Team Vehicles* | 4772.6 | 41903.4 | 50.8 | 101.2 | 42055.3 |
| Volunteers | 97.0 | 852.0 | 1.0 | 2.1 | 855.1 |
| *based on 2023 counts with 85% doing 3-vehicle option, 15% 4-vehicle | | | | **Total** | **42910.4** |

*Table 21 Race day vehicle emissions*

## Lodging

A summary of the information presented in the methods can be seen below, utilizing the proportionate number of room nights for 2023. Just over 36 tonnes $CO_2e$ were emitted with respect to lodging.

| Total Lodging Emissions | | | | | |
|---|---|---|---|---|---|
| **Energy Use Per Night** | | **Total Hotel Room Nights (Double Occ.)** | **Total Energy Use** | | **Emissions (kg)** |
| Electricity (kWh) | 24.6 | 3142.5 | 77306 | kWh | 22300 |
| Natural Gas (mmBTU) | 0.078 | | 245 | mmBTU | 13950 |
| | | | **Total Kg $CO_2e$** | | **36250** |
| Emission Factors | | | | | |
| Electricity | 0.288 | kg/kWh | | | |
| Natural Gas | 56.90 | kg/mmBTU | | | |

*Table 22 Total lodging emissions*

## Food and Beverage

First, there is the vendor emissions summary, which incorporates all of the fuel and food functional unit data gathered and tabulated with respect to their emissions intensities. Each vendor's individual emissions can be seen, and a total value of 4043 kg $CO_2e$ is found attributable to this category. Categories with higher emissions typically have high volume of sales (Boundary Bay), meat featured on the menu (Feast), or a combination of both (El Agave).

| Emissions Summary, Vendors | | | | | |
|---|---|---|---|---|---|
| | **Type** | **Food/Fuel Unit Counts** | **Fuel Emissions Intensity ($CO_2e$/Unit)** | **Total Emissions (kg $CO_2e$)** | **Emissions per Vendor (kg $CO_2e$)** |
| Vendor 1: Mt. Baker Kettle Corn | Food | 150 | 0.2 | 30 | 47.25 |
| | Fuel | 3 gal propane | 5.75 kg $CO_2e$/gal | 17.25 | |
| Vendor 2: Crabby's Crab Cakes | Food | 100 | 2.41 | 240.5 | 246.25 |
| | Fuel | 1 gal propane | 5.75 kg $CO_2e$/gal | 5.75 | |
| Vendor 3: Gusto Pizza | Food | 200 | 1.53 | 306.3 | 384.3 |
| | Fuel | 3 cubic feet of wood | 7.1 kg C per cubic foot of wood; 26 kg $CO_2e$/cubic ft | 78 | |
| Vendor 4: Feast | Food | 300 | 2.53 | 758.3 | 873.3 |
| | Fuel | 20 Gal propane | 5.75 kg $CO_2e$/gal | 115 | |
| Vendor 5: Bay City Ice Cream | Food | 200 | 0.38 | 76 | 76 |
| | Fuel | n/a | n/a | 0 | |
| Vendor 6: El Agave | Food | 400 | 2.45 | 980.7 | 1038.2 |
| | Fuel | 10 Gal Propane | 5.75 kg $CO_2e$/gal | 57.5 | |
| Vendor 7: Boundary Bay Brewing | Food | 4160 | 0.25 | 1040 | 1040 |
| | Fuel | n/a | n/a | 0 | |
| Vendor 8: Ovn | Food | 170 | 1.53 | 260 | 338 |
| | Fuel | 3 cubic feet of wood | 7.1 kg C per cubic foot of wood; 26 kg $CO_2e$/cubic ft | 78 | |
| | | | | **Total** | **4043.3** |

*Table 23 Food vendor emissions summary*

Next, the assumptions regarding food away from home marginal increases are applied at the spatial level, identified with respect to participants with origins within 100 miles and those farther than 100 miles. The assumed extra increased the proportional impact of those traveling over 100 miles due to the assumption of changed eating habits for more instances than those who did not cover the same distance.

| **Distance from Event** | **Racer Count** | **Extra kg $CO_2e$ per person** | **Total $CO_2e$ (kg)** |
|---|---|---|---|
| Within 100 miles | 3142 | 0.7 | 2199.4 |
| Coming from 100+ miles away | 752 | 1.4 | 1052.8 |
| | | Total **$CO_2e$** | **3252.2** |

*Table 24 Food away from home emissions premium estimations by distance*

The volunteer and operations food came to a total of 756.3 kg $CO_2e$. The majority of these emissions can be tied to the 600 packed lunches for volunteers, which had ham as a main contributor to emissions intensity.

| **Item** | **Emissions Intensity ($CO_2e$)** | **Functional Unit Size** | **Ratio of FU to Emissions Intensity/kg** | **Count** | **Total Emissions (kg $CO_2e$)** | **Intensity Estimation Source** |
|---|---|---|---|---|---|---|
| Erin Baker's Breakfast Cookie | 2.73 kg/kg cookie | 16 g | 0.04368 | 2500 | 109.2 | (*Den store klimadatabase*, n.d.) |
| Lunches (ham sandwich, chips, apples) | 2 kg/lunch | 1 lunch | 1 | 600 | 600 | (Heller et al., 2018) |
| Bread | .82 kg/kg | .5 kg loaf | 0.41 | 20 | 8.2 | |
| PB | 2.1 kg/kg | 1 kg tub | 2.1 | 3 | 6.3 | |
| Bagels | .82 kg/kg | 100 g | 0.082 | 72 | 5.904 | |
| Cream Cheese | 8.9kg/kg | 1 kg tub | 8.9 | 3 | 26.7 | |
| | | | | **Total** | **756.3** | |

*Table 25 Volunteer and race packet food provided by Ski to Sea, emissions*

A combined summary table showcases the total of each subcategory, their relative proportions, and the overall emissions attributable to the food and beverage category of Ski to Sea.

| Food Emissions Total | | |
|---|---|---|
| Subcategory | Emissions | Relative % |
| Race Day Vendors | 4043 | 50.2 |
| Operational Food | 756 | 9.4 |
| FAFH Premium | 3252 | 40.4 |
| **Total** | **8052** | |

*Table 26 Food emissions summary*

## Waste

A rough total of 1.3 tonnes $CO_2e$ is attributable to waste by the methods described.

| Category | Count | Waste per day | Waste to Landfill | Landfill Emissions Intensity | Waste emissions per count (kg CO2e) | Total Per Category (kg) |
|---|---|---|---|---|---|---|
| Racer | 3894 | 1 kg | 0.5 kg | 0.57 kg $CO_2e$/kg landfill | 0.285 | 1109.8 |
| Extra Travel days (>370 mi) | 347 | 1 kg, 2 days travel | 1 kg | | 0.57 | 197.8 |
| | | | | | **Total** | **1307.6** |

*Table 27 Waste emissions summary*

## Administrative

A rough total of 3.2 tonnes $CO_2e$ is attributable to administrative energy.

| Energy Source | Area | Usage Rate | Carbon Intensity | Total (kg $CO_2e$) | Sources: |
|---|---|---|---|---|---|
| **Electricity** | 1266.7 | 13.7 kWh/sq. ft. | 0.0995 kg $CO_2e$/kWh | 1727.4 | EIA CBECS, WA Electricity Profile 2021 |
| **Natural Gas** | 1266.7 | 21.8 cubic ft./ sq. ft. | 0.055 kg $CO_2e$/cubic ft. | 1518.7 | EIA CBECS, EIA Equivalencies Calculator |
| | | | **Total** | **3246.2** | **kg** |

*Table 28 Administrative emissions summary*

## Emissions Summary

A summary of the emissions can be seen in Table 29. Values range from 0.75 tonnes $CO_2e$ (0.2% of total) for race operations food to 230 tonnes $CO_2e$ (70.7% of total) for transportation to and from Bellingham.

| **Category** | **Sub-category** | **Emissions (kg)** | **Relative %** |
|---|---|---|---|
| Transportation | Transport Pre/Post | 230383 | 70.7 |
| Transportation | Race Day Transport (Racers) | 42055 | 12.9 |
| Transportation | Race Day Transport (Volunteers) | 855 | 0.3 |
| Transportation | Operational Set-up | 3739 | 1.1 |
| Lodging | Hotels | 36246 | 11.1 |
| Food | Restaurants Pre-/Post- | 3252 | 1.0 |
| Food | Race ops (volunteers, packet cookies) | 756 | 0.2 |
| Food | Vendors | 3923 | 1.2 |
| Miscellaneous | Administrative | 3246 | 1.0 |
| Miscellaneous | Waste | 1307.58 | 0.4 |
| | **Total CO2e (kg)** | **325764** | |
| | **Total CO2e (tonnes)** | **325.8** | |
| | **Average per Participant (kg)** | **83.7** | |

*Table 29 Total emissions summary*

Figures 25 and 26 show the emission values and relative proportions among the subcategories, respectively.

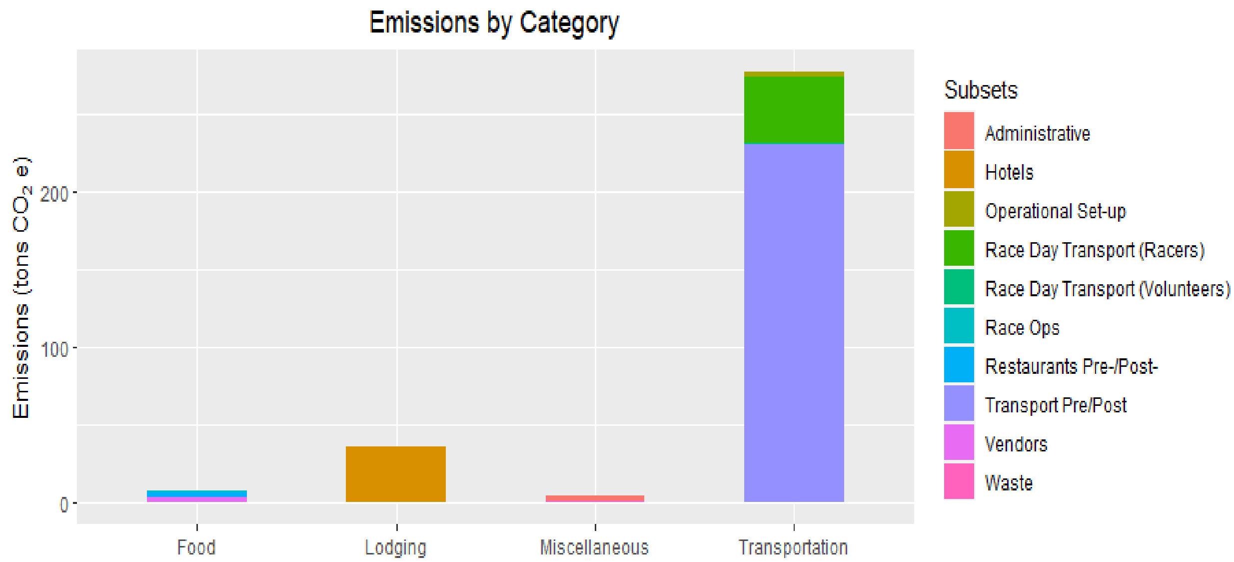


*Figure 26 Ski to Sea emissions by category*

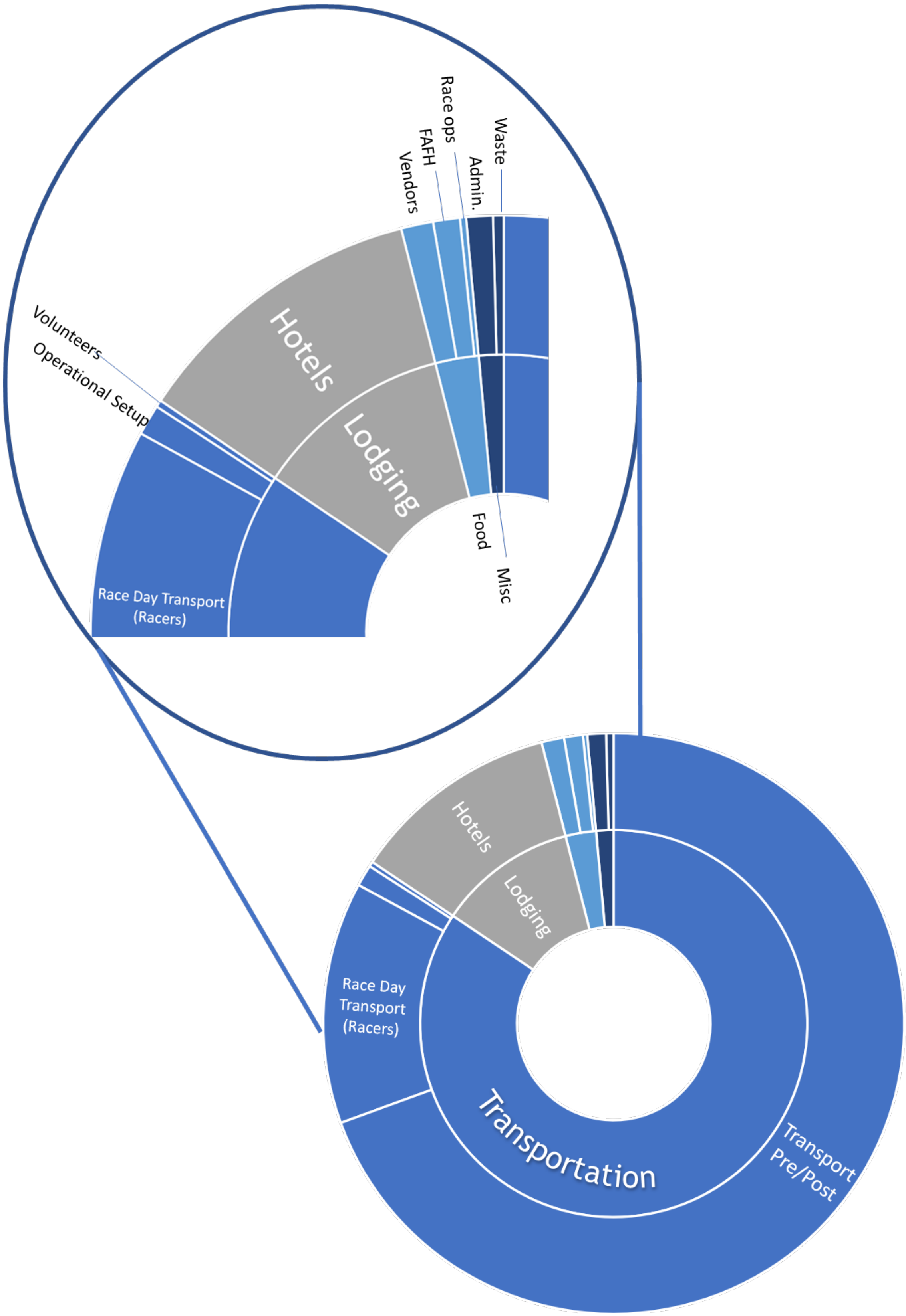


*Figure 27 Ski to Sea emissions proportions*

## Life Cycle Impacts

In 2015, the Paris Agreement was adopted with the objective of limiting global temperature increase to well below 2°C, aiming for limiting the rise to 1.5°C. Overwhelming evidence has demonstrated that $CO_2$ and other greenhouse gases are chief factors in perpetuating global temperature increase, which in turn has myriad impacts on climate stability, severe weather events, agriculture, and economics, with stark and possibly catastrophic consequences for billions of people and large swathes of ecosystems that remain (UNFCCC, n.d.).

Though there are many emissions streams, understanding the predominant impacts on a variety of geographic and environmental scopes is necessary. Clearly, the most important factor in this case is the level of emissions from transportation. With the largest proportion of total emissions at 44%, direct impacts of considerations of aviation are necessary. Though 2.5% of anthropogenic carbon dioxide emissions, aviation can account for 3.5% of warming via radiative forcing (Ritchie, n.d.). With anticipated growth of nearly 4% annually in flights attributed to tourism (UNWTO, 2016), the projected proportion of carbon emissions from flights is likely to overtake passenger car travel for the highest emissions per passenger kilometer (PKM) by 2030 (UNWTO, 2019a). It is clear that a robust strategy is needed to ameliorate the diffuse, though pressing impacts of this particular element of the transportation category. The travel by personal vehicles to and from Bellingham contribute to atmospheric carbon in the same way, just to a lesser extent. On a localized level, the use of cars introduces particulate matter and air pollution that has shown to negatively impact health of those nearby (*Bellingham Climate Action*, 2022). For the race, this localized effect could be seen from within the town of Bellingham to the various large lots allocated for event parking. Addressing the issues related to these emissions streams should thus take precedence.

On this localized level, the impacts of climate change are far-reaching and will affect regions differently. For the northwestern Washington region that this event takes place, an array of consequences may be exhibited with respect to recreation, habitat health, and changes to the overall character of some ecosystems and biomes. According to the US Forest Service's Climate Change Resource Center, a road system analysis for the Mt. Baker-Snoqualmie National Forest illuminated that climate change is expected to have marked impacts on the infrastructure currently in place. Though adaptation measures are identified in the study, some changes likely to be seen include further flooding and necessary crossings due to increased peak flows, cutting off access for both recreationists and forest industry (*Climate Change Resource Center*, n.d.). Already, these impacts can be seen with the closure of FS Road 39, a main access point for multiple trails and mountaineering routes on Mt. Baker, which has been closed due to a wash-out. It is anticipated that further landslides will accompany these flooding events, threatening infrastructure and visitor safety. This, in turn, could mean limiting access for the general public, which can lead to tensions on restrictions (*Climate Change Resource Center*, n.d.).

Elements of these natural places may be at risk existentially due in part to the emissions released in the pursuit of recreating within them, as with the Ski to Sea race. An assessment of the race course can reveal ways that the underlying natural systems that facilitate the race may be altered. It is expected that the region will begin to shift from snow-dominant winters to a mix that includes proportionally more rain in different times of the year, which alters snowpack dynamics and hydrological cycles. This can then impact municipal water use, recreation, and general ecosystem health (James & NFS, n.d.). Accelerated mass balance loss on the glaciers of Mt. Baker has implications for regional ecosystem health, particularly with respect to the water cycles that are central to the area (*North Cascade Glacier Climate Project,* n.d.). The first two legs of the race, the cross country and downhill ski portions, are dependent on snow at the Mt. Baker Ski Area into late May. These snow dynamics will combine with other precipitation and land cover shifts that will propagate in further variable flow conditions of local waterways, such as the Nooksack River (James & NFS, n.d.). This river facilitates the canoeing portion of Ski to Sea.

According to the Washington State Department of Ecology, risks and extent of wildfires has grown consistently and will likely continue to have deepening impact on much of the Western United States. Even with higher precipitation rates than neighboring states, Washington (and the Baker-Snoqualmie National Forest, by proxy) exhibit increased risks of fire directly, as well as lowered air quality from regional fires at large (*Washington State Department of Ecology*, n.d.). Evidence of this nearby can be seen with the 2022 Bolt Creek Fire, which approached the west side of the Cascades near the town of Index, less than 75 miles from the race's starting point (*North Cascade Glacier Climate Project*, n.d.). Though the wildfire season does not yet coincide with the race's Memorial Day weekend date, damage to the ecosystem could affect watershed health and different legs of the race itself.

Finally, the race concludes in Bellingham Bay. This is an area that could exhibit the ill effects of ocean acidification, sea level rise, or flooding events. Additionally, such events can have marked impacts on marine life, related economic pursuits, or culturally significant associations within the habitat (*Bellingham Climate Action*, 2022). In summary, no part of the race will be shielded from consequences of a business-as-usual trajectory, so implementing a plan for emissions and land management would allow for increased resilience and adaptability for the future.

# Part II: Effective Life Cycle Management in Ecotourism

# Chapter 3: Life Cycle Management (LCM)

## Background

To foster progress in decarbonizing the many sources of GHG emissions in travel, application of findings from a comprehensive LCA process is essential. As Mihalic describes, however, the divide between theoretical discourse on sustainability and measurable strides remains difficult, despite decades of research and debate (2016). It is then argued that merging the theoretical discourse on the concept of sustainability with an appeal to responsibility, more commonly associated with action, is a suitable means to enact practical changes within tourism's foundational framework (Mihalic, 2016). The complexity and interweaving among industries upon which tourism is predicated makes defining responsibility difficult, however.

A divergence of thought thus exists as to apportioning the responsibility for emissions between transportation, food, lodging, and infrastructure. Where bounds are defined in any analysis dictate the respective emissions contributions, and economic forces further influence in the split between producers and consumers (UNWTO, 2023). Engaging these various stakeholders in a galvanized framework is necessary to propagate change. As stated earlier, only 20.6% of tourism organizations are accounting GHG emissions at all (UNWTO, 2023). Continued education, standardization, and implementation of LCA techniques is required to help evaluate roles for action to address the responsibility gap that exists among stakeholders.

With this current paradigm, some assert there exists a risk of a tragedy of the commons rooted in which individuals are not beholden to mitigate impacts (Hourdequin, 2010; Johnson, 2003). Hourdequin argues that moral integrity and reconceptualizing the individual to the collective provides an alternative pathway by which beneficial actions and responsibilities can be embraced (2010). Additionally, as Han describes, there are a number of factors that can be leveraged to influence individual decision-making that promote pro-environmental behavior. These include but are not limited to describing social norms, connecting a product or service to nature, education,


*Figure 28 The relationship between climate change and tourism (UNWTO, 2018)*

green imagery, and transference to daily life (2021). It is by this combined framework which the race organizers pursue assessing the impacts and mitigation thereof for Ski to Sea, utilizing organizational and individual motivations for development. Others call upon the private sector to play a more prominent role in developing and implementing solutions, in conjunction with thoughtful policy and increased social pressure (UNWTO, 2018).

To clarify how sustainability could be central to tourism agendas through 2030, Muñoz et al. conducted a meta-study, co-word analysis of the subject. Though a dispersion of topics are identified, four categorical distinctions are made: study and measurement, social sustainability, models of responsibility, and cultural or heritage sustainability (Alonso-Muñoz et al., 2022). Such a variety of academic focuses indicate that a framework of elements will need to be included in an effective solutions framework. Central to the results are the connections between "management" and "community," "perceptions," and "sustainable development." Additionally, the research team identified "circular economy" as an emerging term in the field (Alonso-Muñoz et al., 2022). The momentum behind these terms are emblematic that there is potential in management techniques that combine community-based solutions in line with the priorities of the various locales within which tourism is integrated.

## Life Cycle Management (LCM) Techniques

Given this variety of frameworks proposed in the academic, public, and private sectors, determining feasibility for implementation, scalability, and, perhaps most importantly, efficacy in reducing emissions is vital. Life cycle management (LCM) is a tool that can inform decision-making about these tourism processes, on both the micro- and macro-scales (Filimonau, 2015). LCM offers a solutions-based framework to accompany the results of a given LCA, an essential extension from the foundational insights gained through the initial process. With data-motivated findings and a dynamic ability to assess systems, LCM offers organizations, managers, and even tourists themselves information to reduce emissions in tourism, regardless of location or industry subspecialty (Pryshlakivsky & Searcy, 2021). LCM's overarching conceptual framework oriented around life cycle thinking, bolstered by its inherent flexibility, make it a key candidate for approaching sustainable tourism development.

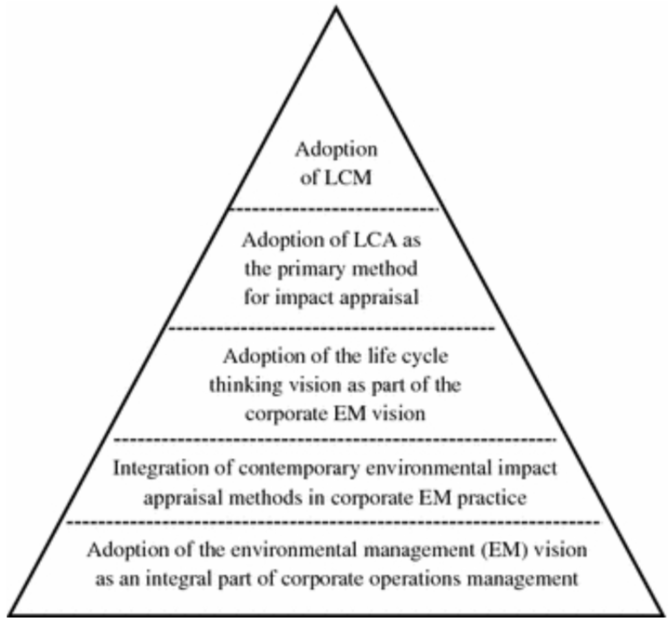


*Figure 29 LCM principles (Filimonau 2016)*

A key factor in LCM practices is ensuring system design, operational development, and active stakeholder choices approach emissions reductions from a practical standpoint. Efforts should be focused to have the largest decrease in impact. A quantitative understanding of a system, standardized methods for data collection and processing, and establishing goals in line with industry-wide changes provide the basis for effective management. Currently, these foundational elements are either missing entirely or implemented in a suboptimal way. According to the World Tourism Organization, only 15% of tourism-based business respondents indicated having established an emissions reduction target by 2030 (2022). Setting such a target allows for the development of a pathway; lacking this element impacts the ability of stakeholders to strategize, invest, and develop the transportation, lodging, food, and infrastructure systems that coalesce to support tourism. For those taking steps in mitigating impacts, a variety of approaches are employed. The three most reported activities include energy efficiency (22.9%), conservation (21.0%), and waste management (19.0%), which all may play varying roles in a solutions framework. However, the WTO's report found that elections for these choices were not grounded specifically due to their mitigation potential, representing a disparity between impact reductions and management choices (2022). Filimonau suggests enhancing academic, private, and policy-based partnerships to develop simple measurement tools that allow for widespread adoption of measurement, goal setting, and mitigation response through an LCM pathway (Filimonau, 2015).

Though flexible in nature, LCM requires some key measures, adapted from Filimonau's work on the subject (2015):

1) Define objectives. Assessing organizational goals in the short, medium, and long terms provides a basis for understanding the approach for an LCA and subsequent management techniques.
2) Conduct the LCA. Identify categories of impact and reasonable approximations for amounts and proportions.
3) Identify areas within organization control or influence and focus efforts there. Determine the reduction potentials with different possible strategies and timelines of implementation.
4) Adopt techniques that can have appreciable impact with respect to what has been identified. Balance what can be implemented immediately with what has the highest potential.
5) Monitor and re-assess on a defined time frame to gauge effectiveness and how to further incorporate reduction measures.

*Limitations and Practical Considerations*

Incorporation of such a methodology over time must include recognition of its limitations, however. Because LCM poses a system of thought based on current LCA systems, some argue that some major areas of consideration are omitted in analysis. For comprehensive effectiveness, LCM must also integrate economic and social factors in developing solutions, areas that are not currently focal points in most tourism-based LCA frameworks (Jeswani et al., 2010; Pryshlakivsky & Searcy, 2021). However, since LCM can be tailored to a variety of situations, Filimonau posits that these factors can indeed be incorporated into an approach, reflecting the priorities of the managing bodies (Filimonau, 2015). Additionally, it is argued that a strictly scientific approach "based on solid procedural rationality can only go so far in terms of influencing decisions" (Pryshlakivsky & Searcy, 2021). Finding a way to combine academic research with the realities of tourism implementation will garner further adoption, accuracy, and application, as increased data from the practice will present conceptual development opportunities, further feeding into effective management for tourism stakeholders. In addition to this, tourism stakeholders may have limited ability to enact emissions reductions, depending on the sources. Pryshlakivsky and Searcy point out that many systems that influence an organization's emissions, like the electrical grid or conventional transportation methods to a place, are outside the realm of influence for many tourism organizations (2021). This said, LCM can still be used to identify where management opportunities for reduction exist within the scope of a particular body. Additionally, there is a particular potential for impact reductions for new enterprises, which can sculpt systems with these goals at the forefront (Filimonau, 2015).

To propagate LCM frameworks, a common understanding of how LCA informs the process is required. As it is conventionally considered academically, LCA has more application as a decision-support tool than as an objectively immutable process (De Benedetto & Klemeš, 2009; Pryshlakivsky & Searcy, 2021). Within the field of LCA, there are myriad assessments of different names and objectives, and within each there are parameters that can be applied in different ways. For any practitioner or researcher, it can be a field with overwhelming choice and nuance, which may be an impediment to beginning active steps towards sustainable management (UNWTO, 2022). There have been strides in standardizing a simplified framework for less academically-inclined stakeholders, which would help to bridge the gap between theory and application (Filimonau, 2015). Conveying the basics of the process and integrating key principles is essential for effective adoption. Consider the Backroads case study; if a simplified model doesn't include guest travel as standard in bounds, then emissions are estimated to be 90% lower than if they had. Simplification can come at the cost of an incomplete picture of organizational impact (Pryshlakivsky & Searcy, 2021), but further systematic studies can illuminate where approximations can be reasonably accurate. For instance, when assessing distance approximations, it was found that Euclidean distance with a ubiquitous detour factor of 1.4 gives a highly correlated value to a more resource-intensive method accounting for travel specifically over a road network ($r^2$>0.9) (Boscoe et al., 2012). Finding reasonable approximations for the most highly emitting categories can help strike a balance between satisficing (accepting what is considered good enough with less resources expended) and optimizing (considering more data and options to find the best possible solution). The balance between these two approaches will be central to how LCA, and LCM by proxy, can be applied to wider reaches in the tourism industry with further academic development (Pryshlakivsky & Searcy, 2021).

# Life Cycle Management for Ski to Sea

With the conclusion of the LCA for Ski to Sea, the race organization faces decision-making choices that align with their objectives of lessening climate impact with presented results. A series of actionable ideas are explored based on reduction potentials, level of influence, and ease of incorporation.

## Participant transportation, to and from Bellingham

An immediate quagmire is presented for management: the most heavily contributing subcategory is one that can only be influenced by the organization to a limited degree, and likely only done so in a way that may impact participation rates. From a managerial perspective, the race organizers could look at the approach in two ways: addressing the majority of racers with action or addressing the most emissions-intensive racers. Without signaling priority, the first segment to elaborate on will be for the overwhelming mode of transport to Bellingham, personal vehicles, followed by how rates of aviation emissions may be addressed.

### Personal vehicles

Based on the rates devised in the travel survey, an estimated 3,626 racers used personal vehicles to get to the race, with 2,639 of those coming from >5 miles away. There are a few ways to decrease emissions when it comes to personal vehicle travel, and they are the same that were incorporated into the emissions modeling. The main points of focus here will be carpool rates and fuel efficiency. To reiterate, average car occupancy for those coming from within 100 miles was 2.82 passengers per vehicle, while the average car occupancy for those driving from over 100 miles was 2.27 passengers per vehicle. Two simple prospective cases are assessed, one in which a single additional person on average rides in each car (3.82 and 3.27 people per car, respectively), and another where 4 people per car is considered across the board.

| Carpool Reduction Rates | | | |
|---|---|---|---|
| | **Emissions reduction (tonnes $CO_2e$)** | **Emissions Reduction % (baseline personal vehicle travel)** | **Emissions Reduction % (total emissions)** |
| 1 person/car increase | 27.2 | 29.4 | 8.3 |
| 4 people per car | 35.6 | 38.5 | 10.9 |

*Table 30 Emission reduction, carpooling*

Around 10% of the race's emissions could be reduced from a change in behavior like this. Given the density of departures from the greater Seattle area, perhaps the messaging forums on Ski to Sea's website could feature a ride share category.

Additionally, the national average for vehicles on today's roads was used as a baseline mpg (24.2 mpg). To change this substantially, a new vehicle is typically required. It would be outside of Ski to Sea's realm of influence to recommend such a purchase, but fuel efficiency gains pointers could be included with the race's messaging regarding its environmental actions. These can include lowering average speed, accelerating and braking gently, and proper tire inflation (US EPA, 2015c). Roughly 3 tons of $CO_2e$ emissions can be avoided per each average mile per gallon increase across all drivers. Though the impacts for transportation may be limited when looking at the event, this would have the co-benefit of decreased emissions with use unrelated to Ski to Sea. Such results would not be quantifiable in the scope of this study, however.

**Aviation**

As referenced, aviation typically counts for a majority of tourism's emissions when it is a mode of travel to a destination. Ski to Sea is no exception to this. As the results demonstrate, flying causes about 63% of all transport emissions, 44% overall. With nearly half of the event's emissions connected to this mode of travel, it must be considered and weighed against the event's priorities. On one hand, the inclusion of participants from all over the country (and some internationally) promotes an exciting dynamic that is enhanced by so many visitors. On the other, intentions at cutting emissions would be underserved without devising some strategy for minimizing this figure. There are three main consumer options that can be considered to lower impacts from aviation:

1) Don't go at all. This is the simplest solution but not in line with race organization goals.
2) Offset the emissions on the voluntary carbon market. This area is currently contentious without consensus on methods, implementation, or efficacy. This topic will be covered more in depth in a later section.
3) Use a different mode of travel, which is less carbon intensive (C. A. Miller, 2021).

Additionally, messaging could be aimed at those flying to consider forgoing a flight at another point of the year they would otherwise fly. Though this would not decrease the emissions associated with the event itself, it may begin to transmit the carbon intensity of flying for personal reflection and action-taking.

**Mode Shift**

With these three considerations, option 3) will be explored here. According to Chester and Horvath, flight emission intensity is lower than personal vehicle travel on a distance basis, when a single driver is assumed (2009). Thus, a mode switch to personal vehicle likely does not make sense, particularly because of the distances involved (some cross-country or trans-Atlantic legs). Conceivably, the two remaining options would be a bus or train. One main consideration in adoption of these modes is the extent to which occupancy rates determine emissions per passenger mile. A train or bus with lower occupancy could have the same or higher emissions per passenger mile. A diesel locomotive (as would be on the Amtrak Cascades train that serves Bellingham) is estimated to have an emissions factor of 0.280 lbs. (0.127 kg) CO2e per passenger mile for typical load rates (Miller, 2021). For buses, an estimated emissions factor of 0.112 kg CO2e per passenger mile was found (Federal Railroad Administration, 2022).

For comparative basis, representative train ride from Seattle station, almost exactly 90 miles distance away, was compared with a comparable car trip. Roughly 1000 participants have origins between 80 and 100 miles away, a great majority of which would be in the greater Seattle area with access to the train.

| Car vs. Train Emission Scenarios, Seattle Amtrak Station | | | | | | |
|---|---|---|---|---|---|---|
| Car occupancy | kg/mile | Difference from train kg/mile | Car Journey Total Emissions per person (kg) | Train Journey total emissions per person (kg) | Difference over 90 mile journey (kg) | % difference from car journey |
| 1 person | 0.376 | 0.249 | 33.9 | 11.4 | 22.4 | 66.2 |
| 2 person | 0.188 | 0.061 | 16.9 | | 5.5 | 32.5 |
| Average Bin 1&2 | 0.133 | 0.006 | 12.0 | | 0.6 | 4.8 |
| 4 person | 0.094 | -0.033 | 8.5 | | -3.0 | -35.0 |
| | | | | | | |
| Train | 0.127 | | | | | |

*Table 31 Emissions comparison by personal vehicle or train, Seattle to Bellingham*

This assessment shows that a blanket statement on mode cannot be made. For the first three cases (car occupancy of 1, 2, and 2.82), the train ends up with varied improvement per person from 66.2% fewer emissions than the 1-person vehicle to under 5% less emissions than the carpool average for bins 1 & 2 (2.82 people per vehicle). Occupancy of both the car and train will be a factor that determines the direction and magnitude of difference between each. Additionally, it would need to be considered whether someone who otherwise would have ridden with someone else in a vehicle switching to a train, thereby decreasing the efficiency of the car journey. The most easily communicated message from this example, as in the context of race organizers to racers, would be there is a marked percentage reduction in emissions from a train trip when compared to driving alone. For a round-trip journey in this case, each person would save roughly 45 kg of $CO_2e$. It would take roughly 22 racers under these particular circumstances to avoid 1 tonne of emissions. While this may be true currently, Miller explains how the case for trains is far more favorable in the instances of partially or fully electric rail (2021). Should infrastructure progress regionally, the scales would more clearly paint a picture for trains, though this as an avenue for full advocacy remains lukewarm.

**Extending the scope of the Car-Free Spirit**

First officially incorporated in 2013, one particularly applicable race division for Ski to Sea to this study is the car-free division. Car-free teams must forego any motorized methods for handling the array of race logistics, including canoe and kayak delivery and racer transport (Ski to Sea, n.d.). Instead, racers leverage human power and ingenuity to handle these systems, typically completed over multiple days with the aid of bikes, trailers, and planning. Given that the farthest three legs are 56 miles away (with 6100 vertical feet to cover in that distance), and specialized equipment like skis and boats must be transferred in advance, this division offers both heightened challenge but also a sense of adventure. For the 2023 race, only 7 of the 479 teams competed in this division.

On the practical level, these teams save roughly 100 kg of $CO_2e$ each by avoiding car-travel race day. Altogether, less than one tonne was avoided among the division's participants.

This doesn't take into account the extra food that likely was needed for this feat of endurance. However, there is a powerful symbolism that may be able to be tapped for future races. Rather than focusing the narrative strictly on numbers in this case, can the spirit of this division be leveraged for actionable changes that do in fact have larger emissions implications? The first obvious choice would be to increase the rate of teams participating in this division. Not only would emissions be avoided, but less race day traffic would decrease local particulate matter at each of the race sites. In an informal race-day survey, many respondents indicated an interest in participating car-free; considerations for tutorials, featuring racers, or other incentives could spur further participation to enhance the culture of adventure that accompanies this way of competing.

The less obvious, but perhaps more effective method of reducing emissions, would be to expand the scope of what car-free represents. Thousands of participants live within 100 miles (n=3142), many of which have nearby access to rail travel, which is the easiest way to travel appreciable distances by bike without the need for lengthy boxing process. Designing a tutorial for utilizing the train system and local bike travel could lessen the emissions burden for travel to and from Bellingham for those traveling solo or in pairs, and it can be framed for the experience, not simply as a means of reducing greenhouse gas emissions. Further logistics for race day would need to be considered, particularly for heavy and specialized equipment, though a centralized system for these participants could be devised—could canoes and kayaks be crowd-sourced and delivered, building out infrastructure at a small level to begin then expanding with time? The idea of car-free past the boundaries of Bellingham do indeed incite many questions of feasibility, but it also instigates thought for a holistic transformation that could accommodate racers willing to attempt the challenge, while decreasing emissions in the process. Categorically, ingenuity and unconventional thinking would likely need to be used to make significant reductions in transportation to and from Bellingham. This would also need to be weighed against the conclusions made regarding the emissions between trains and personal vehicles identified prior.

## Participant transportation, race day

From conversations and informal data gathering at three sites on race day, the single most cited recommendation from those in the crowd was for a bus system to and from the race sites. This would come with extra logistics organizationally, as well as extra expense. However, given the volume of traffic and specific locations, such an endeavor could lead to direct emission reductions. Buses can fit a variety of numbers, in the range of 24-56 people. For instance, the leg to and from Heather Meadows can be assessed. If teams do 4 teammates on this driving leg, as is advised, 472 teams driving this 113-mile round trip distance with an average mpg of 17.5 would emit 26.8 tonnes of $CO_2e$. A simple calculation that assumes 40 buses carrying those same people (roughly 50 people per bus) with a fuel efficiency of 6 miles per gallon (*Alternative Fuels Data Center*, n.d.), just over 6.6 tons of $CO_2e$ would be released, a reduction of 20 tonnes with this operational shift. However, a large caveat looms for such a change. The current paradigm has the bike rider dropped off 10 miles from Heather Meadows. Transporting hundreds of bikes, each worth up to thousands of dollars, would likely be a challenge that may limit participant desire for use en masse. The same could be said for the skis and snowboards used at Heather Meadows as well, though these are more easily transported and less fragile than carbon fiber bikes, in particular. Again, this idea could be explored, but it would not be without its challenges.

## Lodging

The only measured impact source for lodging was in the estimates made for local hotels. Local camping areas, home stays, or camping nearer to the race legs could be recommended to the participants for the night before. For each room night opted out of, just 11.5 kg of $CO_2e$ would be avoided. The magnitude here doesn't seem as though it would be enticing for operational influence, and the economic activity that accompanies hotel stays is typically welcomed by the city for its tax revenue and community at large for the commerce. Like with recommending participants take steps to increase their vehicle's fuel efficiency, a more general approach that advocates for the partnering hotels to reduce their own emissions operationally would have both nightly impacts for Ski to Sea's guests, reduced emissions all other times of the year, and possible financial savings depending on the measures taken.

## Food and Beverage

Food and beverage constitutes a category that exhibits organizational influence to a degree but a lesser magnitude than the likes of transportation and lodging. With this, options that influence transference may be advised. Since meat and dairy products account for roughly 75% of all emissions in a given diet for an average American, enlisting vendors that feature plant-based menus could have a sizable percentage reduction in total emissions (Heller, 2018). The single largest vendor contributor to Ski to Sea was Boundary Bay Brewery, due largely to Ski to Sea ordering volume enough for all participants for the end of race celebration. As beverages are third in line behind meat and dairy in Heller et al.'s 2018 study, the emissions intensity coupled with this volume represent its total impact. It would be ill-advised to suggest curtailing this expected and enjoyed tradition, unless the goal is to draw the ire of thousands of Pacific Northwestern outdoor athletes.

## Culture

An overarching element that is interwoven among the race organizers, participants, volunteers, and community is that in values and culture. Every respondent to the race day survey indicated that addressing environmental impact of the race was either "very important" or "important," with no responses below that. Knight and Hao conclude that those who participate in outdoor recreation are more likely to have concern about climate change (2022). This presumed care among the race community can be leveraged to communicate not just impacts, but solutions for these challenges. As the race organizers aim to take responsibility in the pursuit of this study, so too can this information be imparted with the goal of fostering not just dialogue but action as to how Ski to Sea can reduce its environmental impacts.

## Aggregation of reductions

| **Aggregated Reduction Methods** | | |
|---|---|---|
| | Assumed method | Avoided Emissions (tonnes $CO_2e$) |
| Carpool | 1 extra person per vehicle | 29.4 |
| Mode Shift | 50 solo drivers taking a bus or train | 2.3 |
| Lodging | 5% efficiency and habit measures | 1.8 |
| Food | Have 1/3 of participants choose plant-based food | 1 |
| Car-Free | Ten new teams | 1 |
| | **Total** (tonnes $CO_2e$) | **35.4** |
| | **% reduction** | **10.9** |

*Table 32 Emission reduction summary, incremental changes*

With these introductory, incremental changes, this 35-tonne decrease would curtail over a tenth of the event's emissions. Should these priorities become more entrenched in the race community, changes to a stronger degree could be pursued, particularly in influencing transportation to and from the race. Though not a formal recommendation at this stage, some race events are being held as "no fly," meaning entry and participation is predicated on travel to and from the race without taking a plane to get there (*GBDURO*, n.d.). Should this more drastic identity shift be adopted, 137 tonnes $CO_2e$ would be avoided. In conjunction with the other techniques above, a 53% decrease could be seen. This would of course have major implications for race messaging and social discourse around the topic, but such topics are not within the scope of this paper.

| Aggregated Reduction Methods | | |
|---|---|---|
| | Assumed method | Avoided Emissions (tonnes CO2e) |
| Carpool | 1 extra person per vehicle | 29.4 |
| Mode Shift | 50 solo drivers taking a bus or train | 2.3 |
| Lodging | 5% efficiency and habit measures | 1.8 |
| Food | Have 1/3 of participants choose plant-based food | 1 |
| Car-Free | Ten new teams | 1 |
| No-Fly | Race arrival without plane | 137.3 |
| | **Total reduction** | **172.7** |
| | **% reduction** | **53.0** |

*Table 33 Emission reduction summary, identity change (no-fly) included*

# Chapter 4: Carbon Neutral Ecotourism

## Considerations for Efficacy

In the greater environmental context, one approach that has been in development for decades is balancing emissions released through operations with reducing greenhouse gas emissions from another stream or sequestering it directly (US EPA, 2015a). In organizational application, a variety of definitions and their nuance points have evolved over time, chief among them is the distinction between "carbon neutral" and "net zero." For carbon neutrality, mitigation methods can include credits based on avoided emissions, as defined in the Publicly Available Specification (PAS) 2060 standard. "Net zero," however, has informally evolved to build upon this with mitigation methods that remove atmospheric carbon in line with the amounts emitted (Allen et al., 2022). Claims to being carbon neutral or net zero are often fraught with issues regarding boundary setting during life cycle accounting, offsetting efficacy, and organizational framing (Allen et al., 2022). Tourism organizations and stakeholders have begun to adopt strategies to also claim a carbon neutral or net zero status. Foundationally, it is important to identify the three key elements of a voluntary carbon neutral target:

1) the boundaries defined for measurement,
2) the methods employed to reach the objective,
3) the defined timeline (Allen et al., 2022).

In an earlier study looking at the conceptual framework for carbon neutral destinations, Gössling describes how some initial destination countries aimed to decrease emissions and offset the remainder, most commonly through forestry schemes (2009). As the field developed, it was found that policy did not keep pace in fostering appreciable emissions reductions in the tourism sector, also lacking in private investment for initial reduction measures that should be central to a sustainability plan (Gössling et al., 2013).

Identified as central to this conversation and recurring in this study, is how tourism can approach a decarbonizing strategy with respect to aviation. It was found that current policies through the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) framework will not lead to emission reductions towards net zero as claimed (Larsson et al., 2019). Additionally, policy choices regarding technology, transport demand, and social norms were assessed, and voluntary offsets were identified as one of the likeliest policies for effectiveness as aviation emissions are expected to grow. However, two caveats accompany this. First, the offsets must be a complement to reduction strategies, not a standalone option. Next, options with scientifically proven ability to reduce carbon must be identified and pursued (Gössling & Lyle, 2021).

Due to the defined link between events and tourism emissions sources, these considerations are also required when assessing tactics to foster a carbon neutral or net zero event. Thus, decarbonizing strategies developed for tourism have direct usage for meetings and events (UNWTO, 2023). As described earlier, pursuits for net zero events have typically occurred with generous funding schemes for mega-events, like the Olympics or FIFA World Cup. Strategies for medium and small events, for which carbon accounting and developing neutrality paradigms are typically cost-prohibitive, have yet to be standardized or a point of focus (Dolf, 2017). Thus, information gained from the hypothetical process of achieving a carbon neutral Ski to Sea can proliferate to other similar events.

The FIFA World Cup can provide a baseline understanding of considerations for aiming for a net zero event. The progression of World Cups from 2006 to 2022 can signal inclusion of sustainability concepts, though claims of being net zero have incited doubt in the scientific and social spheres. The 2010 World Cup in South Africa featured central messaging about mega events' sustainability and emissions, but mitigation action was piecemeal and deemed a missed opportunity for effectiveness and symbolism (Death, 2011). For the 2014 World Cup in Brazil, a disconnect between the goals and actual outcomes the major forestry project devised to offset a new stadium's construction was identified (Crabb, 2018). The most recent World Cup was accompanied by claims from FIFA that the event was carbon neutral (*Sustainability | Qatar 2022*, n.d.). However, points that illuminate questionable accounting strategies, overly optimistic offsetting capacities, and project deliverables showed credibility in these claims was lacking (Carbon Market Watch, 2022). Though the World Cup differs in many ways from a small event like Ski to Sea, themes to consider are integrity in the accounting process, a focus on verifiable results, and the need for evidentiary claims.

## Offsetting as a Method of Greenhouse Gas Mitigation

In theory, carbon offsets can act as a method of balancing emissions by absorbing atmospheric carbon or avoiding emissions from what would have been released to the atmosphere without intervention. To date, nearly all voluntary carbon market credits issued (96%) have been purchased on the basis of emission reduction or avoided emissions (Allen et al., 2022). Offsets have been defined from varied source streams, as with reforestation, renewable energy transition projects, changes in agricultural practices, and changes in landfill and waste management (*Carbon Offsets*, n.d.). For offsets to be deemed effective, they must adhere to four principles:

1) Additional: The offset must come from an activity that would not have occurred otherwise.
2) Quantifiable: The offset must measurably reduce emissions.
3) Permanent: The greenhouse gases reduced must remain out of the atmosphere.
4) Real: The offsets must be third-party verifiable (Schmidt, 2009).

In recent past, offsetting structures have caused controversy based on claims that they have been largely ineffective. One such report that caused stir was from the Guardian, stating 90% of Verra carbon offsets were to be considered worthless with respect to their claims (Greenfield, 2023), though Verra refuted these claims and defended their methodologies (*Verra*, 2023). An additional study estimated that roughly half of approved carbon offsets in a case of Indian wind farms through the Clean Development Mechanism did not meet the standard of additionality (Calel et al., 2021). The variety of possible options, and the physical constraints that emissions avoided does not physically reduce the atmospheric carbon level that increases from unabated emissions, shows that scientific guidance and standardization in offsets is vital to real progress (Allen et al., 2022).

**Nature-Based Solutions for Sequestration**

One promising subset of offsets that has potential for both its carbon sequestration potential and its myriad co-benefits is with nature-based solutions (NBS). Nature-based solutions can add to overall ecosystem health locally, increase community climate-resilience, and be cost-effective in providing benefits to society when compared to their conventional counterparts (Seddon et al., 2020). Benefits that include water quality, air filtration, erosion control, and citizen wellbeing are among the many that have been identified (UNWTO, 2023). Nature-based solutions that are specifically developed with respect to their potential in mitigating impacts from greenhouse gas emissions are referred to as “natural climate solutions,” which utilize techniques for forests, wetlands, grasslands, and agricultural lands. It is estimated that natural climate solutions (NCS) can provide up to 37% of cost-effective $CO_2$ mitigation needed through 2030, which would maintain chances for limiting warming to below 2 °C to over 66% (Griscom et al., 2017). These methods have found particular importance in nature-based enterprises, and connecting this shared component in nature can be used to expand implementation. Ecotourism is one such area where this potential lies (Kooijman et al., 2021). Based on the WTO’s Baseline Report on Climate Action in Tourism, NCS actions are already becoming entwined in the industry’s climate framework:

“Most respondents (69%) reported that they do not purchase offsets and 20.6 % indicated that they offer clients the option to compensate their emissions. Out of the 10% of respondents which are purchasing offsets, 32% say they are supporting nature-based solutions; 17% are supporting technology-based solutions. From those investing in nature-based solutions, the majority support reforestation projects and conservation and some support coral restoration and mangrove protection, while just one mentioned biochar production and another one mentioned kelp farming” (2022).

Inclusion of NCS techniques can also enhance the ecotourism systems at large. It was found that multiple tourism development dimensions, including governance, management, capacity building, visitor management, and sustainable financing stood to have improved outlooks from appropriate nature-based solutions (Mandić, 2019). Thus, a symbiotic system that involves ecotourism development with corollary impact reduction measures that promote natural health is possible. Further research and standardizing the methodology for calculating emissions avoided via the various NCS techniques will allow for a wider spread implementation. Already, frameworks exist for pursuing shared natural spaces all over the country. Such frameworks can be utilized or mirrored to increase NCS implementation; one such example is held in the conservation easements in the US (S. Hollenhorst & Clark, n.d.). It is through these connections that a paradigm of regenerative tourism and recreation can be developed and expanded.

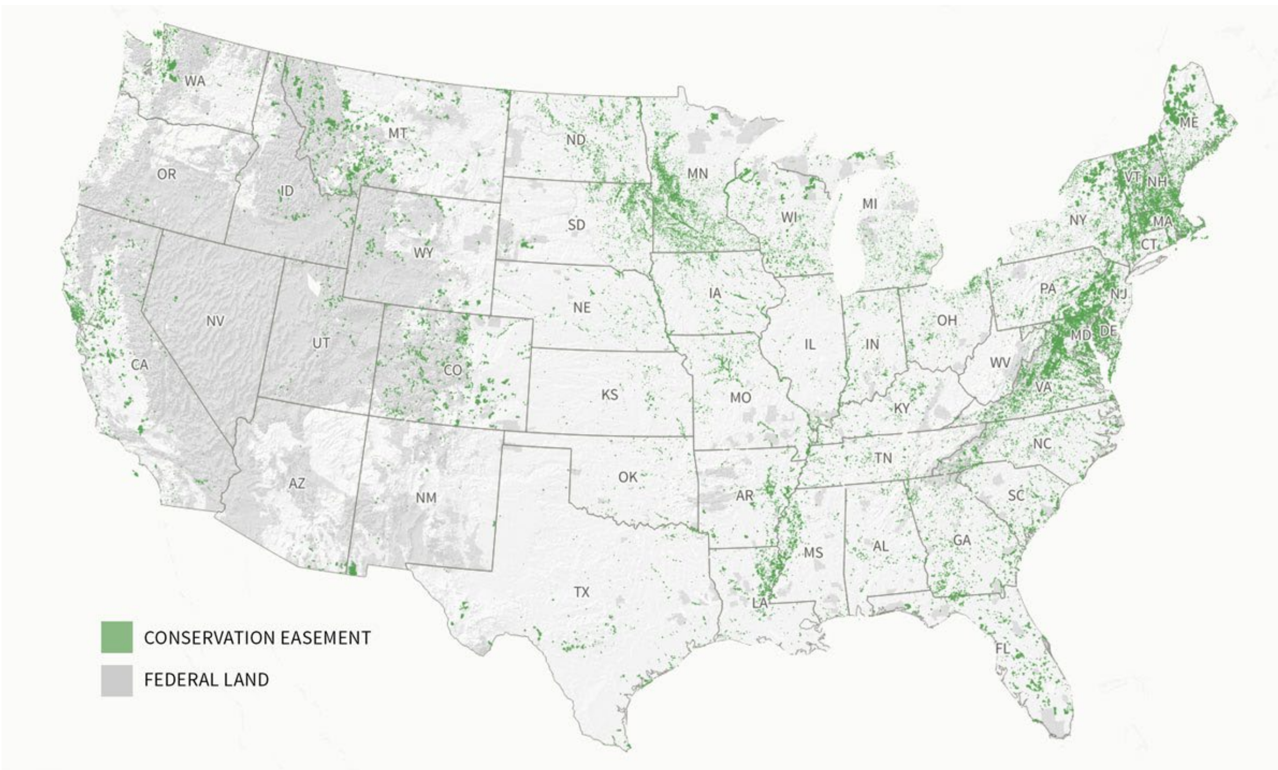


*Figure 30 US national map of federal lands and existing conservation easements (S. Hollenhorst & Clark, n.d.)*

With such a broad geographic range available to employ solutions, the variety in climates, ecosystems, and physical conditions will lead to a need for a similar range of solutions. Connecting appropriate solutions, some of which are identified with the corresponding sequestration potentials (Griscom et al., 2017), with what is naturally tenable is an area that will require further research and development.

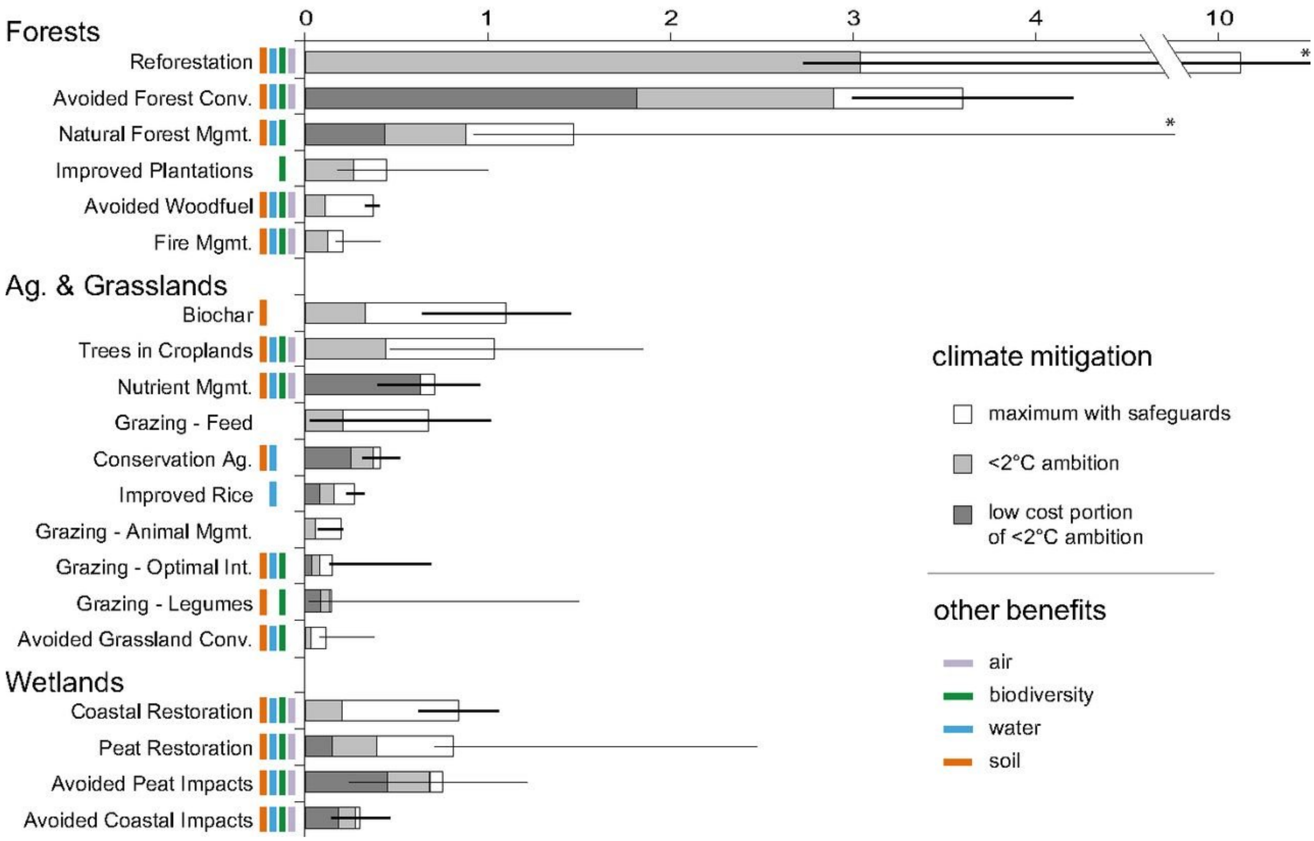


*Figure 31 Natural climate solution by type, climate mitigation potential, and co-benefits*

*Integrating Communities into Nature-Based Solutions*

The potential for leveraging reciprocating benefits is not limited to just the relationship between ecotourism and cultivating natural systems. Social benefits stand to increase through the implementation of natural climate solutions, which can further ecotourism pursuits as well. According to the IPCC, "there are significant synergies that can be exploited in bringing climate change to the development community and critical development issues to the climate change community. There is an important opportunity for the tourism sector to show leadership in the development of a coherent policy agenda that integrates both development and climate change perspectives" (UNWTO, 2008). The community focus of well-planned ecotourism can engage local people and visitors alike, integrate natural climate solutions that are appropriate for the resources available, and in turn provide further data for academic and policy development.

First, broad swathes of research have identified the connection between human well-being and contact with nature. As outlined in Frumkin et al.'s meta-study on this relationship, access to and time with nature improves mental health by reducing stress, depression, and anxiety; improves physical health by strengthening immune function, reducing obesity, and generally increasing health across adults, children, and cancer survivors; and improves social and emotional health through increased prosocial behavior and social connectedness (2017). Furthermore, nature-based solutions for ecosystem-based problems can have a central co-benefit of increasing citizen health and wellbeing (Kolokotsa et al., 2020). This relationship can be used to develop local recreational opportunities, which then increase pro-environmental behavior (Larson et al., 2018). Since commitment to environmental stewardship is strongly influenced by attachment to place and recreation involvement (Lee, 2011), a community-wide priority on nature allows for a more robust foundation for integrating natural climate solutions.

Additionally, a focus on community systems allows for further economic development through ecotourism. The attachment and stewardship just described provides more physical spaces for recreation, which can then be shared through tourism pursuits. Ecotourism in protected areas can provide financial stability for a community, further economic opportunity for local citizens, and continued motivation for stewardship and protection of natural spaces (Snyman & Bricker, 2019). An example that may be utilized in developing ecotourism with accompanying natural climate solutions exists in the current system for recreational hunting and fishing. Permits are issued based on capacity, with proceeds going to managed lands and waterways which facilitate that recreation. For instance, access and hunting permits can assist with needed population management, as with deer, at a lower financial burden than would be otherwise (Fraser, n.d.). If economically-motivated access to nature shares in impact mitigation through natural climate solutions, then a holistic system that fortifies ecosystem and community health may be achieved. Figure 31 illustrates the relationship between natural climate solutions, ecotourism, and communities.

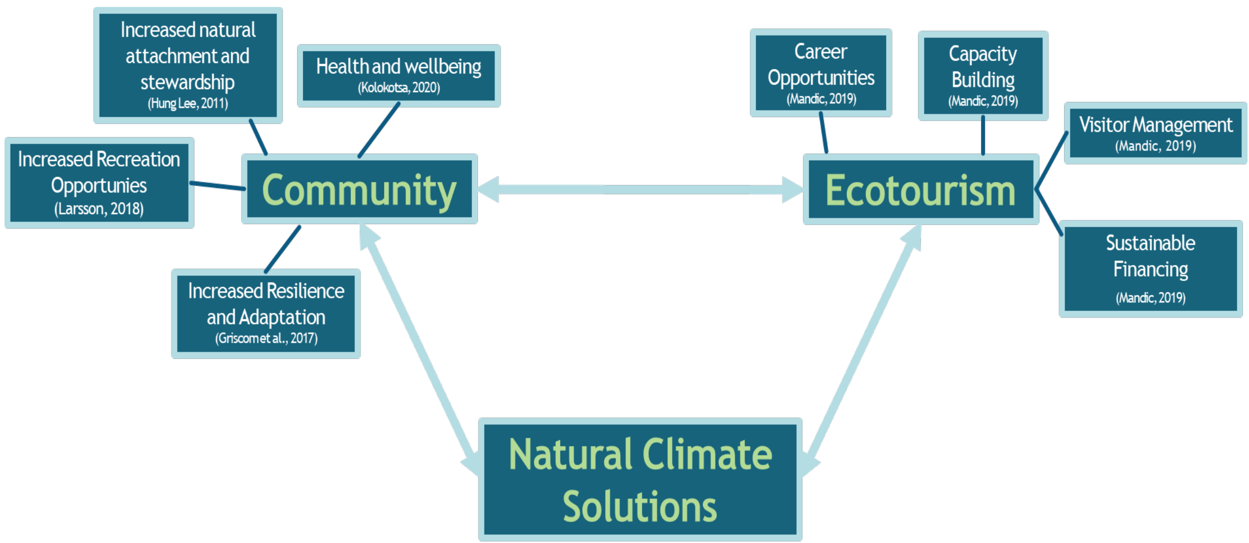


*Figure 32 The reciprocal relationships among ecotourism, communities, and natural climate solutions*

**The Carbon Trust Model**

One framework that connects communities, economic pursuits, and NCS strategies is in the establishment of a carbon trust. Essentially, a carbon trust is an innovative way to combine elements of land trusts, workforce development, cooperative extension, and green finance into integrating natural climate solutions into communities to mitigate atmospheric greenhouse gas impacts (Hollenhorst, 2022). The physical approach is to convert atmospheric carbon into elements of the biosphere, lithosphere, and pedosphere to deliver co-benefits, as previously described. By utilizing established methods of easements for land conservation, carbon networks will be able to be managed, expanded, and protected, serving as community-based solutions that will in turn provide improvements for citizen wellbeing, ecosystem quality, and municipal systems (Hollenhorst, 2022). These carbon asset owners would be financially supported by carbon offset buyers through an interwoven network of community engagement and property management, all influenced by critical legal, market, and social forces (Hollenhorst, 2022). As this model is contingent upon a place-based and nature-based foundation, inclusion of ecotourism as an arena for development would spur mutual success in the intended goals of each.

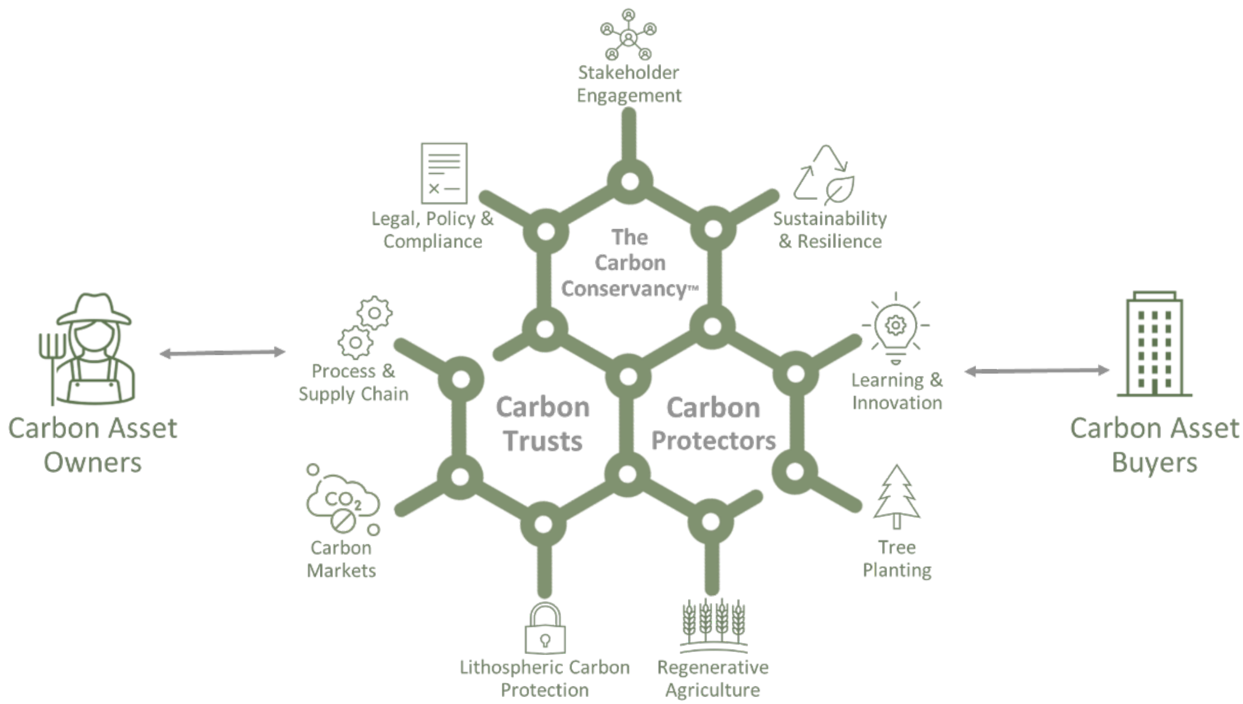


*Figure 33 The Kulshan Carbon Trust representation of a carbon economy (S. Hollenhorst, 2022)*

## Offsetting Strategy for Ski to Sea

It has been established that the first order of pursuit for Ski to Sea would be to utilize life cycle management to reduce emissions in connection with the event. The track that is pursued then determines the remaining emission burden to be addressed with NCS projects, as with the incremental pathway that reduces emissions just over 10% or the identity shift with curtailing flights at over 50% total reduction.

A developing carbon trust local to the area is the Kulshan Carbon Trust, which has piloted some projects utilizing biochar as an NCS (Kulshan Carbon Trust, n.d.). Generally speaking, burning or natural degradation of organic feedstocks or materials introduces more atmospheric carbon to the air. Biochar is the result of those inputs undergoing pyrolysis instead, converting would-be atmospheric carbon to a more stable form for the pedosphere. This biochar can then be used as a soil amendment for agriculture or agroforestry (Panwar et al., 2019). It includes the co-benefits of nutrient absorption and retention, erosion control, and resulting decrease in eutrophication potential, as when applied in an agricultural context (Ding et al., 2017). Biochar is deemed a suitable approach regionally, as inputs are abundant with the forest resources and associated industries like logging (Kulshan Carbon Trust, n.d.). Typically, existing methods retain roughly 50% of carbon from the feedstock (US Biochar Initiative, n.d.). However, this can vary substantially based on production method (Panwar et al., 2019).

Based on the mitigation capacity needed, additional projects could be developed locally that are either funded by racers or even tended via volunteering. These projects could also take place at different places along the racecourse, visible to participants with a corresponding educational opportunity at the race transition areas. Nuance points as to whether the event organizers would spread the emission burden across all participants in project funding or have them be proportionately determined based on racer factors (particularly distance traveled) would be central to devising a strategy for supporting these projects. However, this presents a new opportunity for corporate "carbon sponsorship," in which local businesses could fund a portion or all of the biochar projects needed to sequester what remains after reductions have been realized. Since Ski to Sea is a community-wide event, the same inclusion of community stakeholders would allow for collaboration and cooperation to facilitate the biochar and subsequent application to the benefit of Bellingham at large. A table that outlines pricing based on reduction strategy can show total cost and cost per participant for the 2023 race, assuming carbon offset purchasing at \$100/tonne $CO_2e$.

| Offset Pricing, by Case | | | | |
|---|---|---|---|---|
| **Reduction Case** | **Reduction (tonnes $CO_2e$)** | **Total Remaining Emissions (tonnes $CO_2e$)** | **Total Cost, Est. \$100/tonne $CO_2e$ avoided (\$)** | **Cost per participant (\$)** |
| Business as Usual | 0 | 325.8 | 32580 | 8.37 |
| Incremental Shifts | 35.4 | 290.4 | 29040 | 7.46 |
| Identity Shifts | 172.7 | 153.1 | 15310 | 3.93 |

*Table 34 Offset pricing by reduction case*

# Chapter 5: Future Considerations, Research Opportunities, and Conclusions

## Emissions by Tourism Subcategories

Currently, there is an existing deficiency at a granular level regarding tourism types and associated emissions. Though the categorical contributors to emissions have been identified, with a special emphasis on transportation, is there a means of defining reasonably standardized emissions by experience type? The goal would be to determine how tourism types differ in emissions, such as highlighting a typical cruise, national parks road trip, or a local retreat would compare. A financial component could then be incorporated, understanding how money spent in each respective activity is possibly connected to the emissions streams.

Additionally, there is more development to be done regarding accounting for the "do nothing" alternative when it comes to tourism. Should a trip or trip component (such as a flight) be opted out of, what would a hypothetical tourist emit in that time instead? If they were to stay at home instead of taking a trip at a greater distance, determining an accurate emissions differential between the two situations would allow for a more informed perspective on how tourism management choices impact the actual amounts of greenhouse gas emissions as a whole.

## Developing NCS Capacity

Already, there is varied and deep research as to the mitigation potential and application of natural climate solutions on a national and even global level. However, there is a need for further understanding the impacts on the ecosystem and landscape scales that such solutions will need to be implemented for measurable effects globally. Further research will be needed for local and regional scales to ensure effective, equitable, and inclusive strategies (Novick et al., 2022). Currently, there exist resources for understanding what geography-specific steps can be made to reduce emissions. One example is Climate Central's system that identifies each state's best potential area for reductions, categorically (2023). Further development of such opportunities specifically for natural climate solutions could illuminate paths forward for individual communities aiming to employ the most effective solutions nearby.

There is also growing potential for research between natural climate solutions and psychology. Is there a connection that exists to be leveraged for greater implementation, efficacy, and overall stewardship? The American Psychological Association recognized that climate change is likely to have profound influence on mental health, as well as its influence on individual perceptions and actions (2009). Understanding the motivations and discouraging elements of evolutionary psychology can be utilized to catalyze change (Palomo-Vélez & van Vugt, 2021). On top of this, Ojala identifies a positive relationship between hope and climate change engagement (2023). Thus, there may be a means of combining established understandings of positive impacts nature has on psychological wellbeing with wider adoption and public support for natural climate solutions.

## Pricing NCS within the Voluntary Carbon Markets

Understanding and appropriately pricing natural climate solutions will be necessary for widespread market adoption and systematic implementation. For instance, contrasting NCS strategies with purely technological ones may be illuminating. A commonly employed method of greenhouse gas mitigation reduction accounting is through marginal abatement cost (MAC) curves, which consider abatement measures solely on emission reductions and financial factors (Kesicki & Ekins, 2012). There are currently multiple crediting systems being developed that aim to encompass the co-benefits that are not currently accounted for in MAC curves, but they are not yet standardized or ubiquitously accessible (Su & Peng, 2020). Progress will be needed here to better ascribe value to ecosystem benefits that accompany NCS strategies.

In keeping with this comparison, a more robust understanding of how to include a time element for different offset types will play a role in the financial valuations. Discount rates have a significant impact on valuations for offset projects, based on what percentage is included for the calculation (Emmerling et al., 2019). This effect has traditionally posed a barrier for natural climate solutions, which indicated an advantage for immediately deployable solutions over NCS strategies, which take longer to realize their respective sequestration potentials. This time preference is shown to be lacking in accounting for the true social cost of carbon, however (Parisa et al., 2022). By better defining the time horizon of mitigation methods across different categories for climate solutions (technological, social, or natural), a clearer picture for pricing and comparison will emerge.

## Direction of Tourism at Large

Finally, an assessment as to the guiding principles of tourism may need further consideration. Refined understanding of the motivations, rewards, and decision-making processes for choice of destination, activity, and connection to environmental impacts will be informative for the industry at large. As it stands, this analysis aimed to assess the existing tourism paradigm through an individual event, without considering some of the foundational elements involved. Fennell argues that a major motivator in tourism is *novelty* of experience (2008), so better understanding how this can influence decisions for tourism could be important. It is argued that a new approach to tourism, *locavism*, may better serve the industry and communities that facilitate it. Key tenets of this shift would be replacement of the current system with an emphasis on local destinations, short distances, and lower-carbon infrastructure at the core of operations (S. J. Hollenhorst et al., 2014). Local *microadventures* may also play a role in such a process (Mackenzie & Goodnow, 2021). Thus, continued efforts at changing how people engage in tourism may be a more effective method of reducing emissions than developing a complementary system of natural climate solutions alongside the status quo. Further exploration into these subjects may reveal different paths forward for reducing emissions and developing enriching and accessible tourism frameworks.

# Conclusion

The intention of this study was to identify the climate impacts of ecotourism, understand their classifications and relative magnitudes, and devise a solution framework by which pursuits in this industry could mitigate those impacts. The Bellingham-based eco-event, Ski to Sea, served as a proxy for developing this framework. LCA techniques were employed and refined to accurately approximate the event's $CO_2e$ emissions, and combining LCM techniques with an appraisal of the current state of affairs of offsetting provided a theoretical basis for achieving carbon neutrality. This process can be emulated for a variety of other ecotourism opportunities, but application can also be found in other industries that are also place-based and nature-based.

The LCA for Ski to Sea yielded results that were in line with multiple other studies. The chief contributor to emissions was transportation (approximately 83%), particularly in participant travel to and from Bellingham (approximately 70% of total). This subcategory in consideration had a particular focus with the pre-emptive survey that had 401 responses to inform assumptions regarding the modes and various factors that influenced transportation. Lodging consisted of just over 11% of impact in the form of estimated hotel usage, and food contributed less than 3% after factoring in vendors, marginal increases in eating food away from home, and organizational food for volunteers and in race packets. Altogether, roughly 325 tonnes of $CO_2e$ were emitted in connection with the 2023 Ski to Sea race; among the 3894 participants, the average emissions per racer came to 83.7 kg $CO_2e$. These results provided the baseline by which further management options could be considered. The process here was consistent with other studies but was still more time and computationally intensive than an average stakeholder may be able to commit. As such, further standardization that maintains an acceptable level of accuracy with the minimum necessary inputs would help a broader range of stakeholders engage in this initial accounting process. A particular focus should be directed towards transportation, if resources are limited.

The inclusion of a solutions framework provides a more robust ability to reduce emissions and make decisions regarding operations, choices, and default behaviors of participants. Using a life cycle management approach allows stakeholders to incorporate results of an LCA, while also being able to consider other elements inherent to organizational process. By identifying the sources to the sub-categorical level, opportunities for the largest reductions in magnitude and those most easily implemented come into focus. LCM can provide quantitative evidence for decision-making, particularly when an organizational goal is the reduction of greenhouse gas emissions. For Ski to Sea, as for other existing ecotourism bodies, options exist that range from lower GHG reductions but lower barrier to action, to those with higher reductions but higher barriers to action. Across this spectrum, an organization would almost certainly be considering fiscal factors as well.

The standout option for easily administered changes would be advocating and perhaps helping to organize increased carpool ridership, particularly due to the density of participants from Seattle. This had an estimated reduction of nearly 30 tonnes $CO_2e$, if the average car occupancy increased by one from 2023 values. Other low barrier options had negligible reduction values (<1% each). These options characterized what were deemed to be incremental shifts to the process. One higher barrier option with higher reduction potential defined was to make this a “no fly” event. This would thus be characterized more so as an identity shift. The inclusion of this strategy would reduce event emissions by 44% alone. This constitutes a shift with significant possible implications logistically, socially, or politically, however.

One common goal among organizations cross-industry today is to achieve carbon neutrality. An approach that combines LCM-based changes with a local, nature-based offsetting strategy could provide specific benefits to ecotourism stakeholders. Natural climate solutions, when employed appropriately, can provide co-benefits that increase community wellbeing, ecosystem health, and economic potential for nature-based enterprises. For Ski to Sea, working with the local carbon trust to develop biochar projects that are visible from the racecourse would aid in avoiding emissions that would otherwise occur. Offsets purchased from NCS strategies at \$100/tonne $CO_2e$ avoided would add between \$3.93 and \$8.37 additional fees for participants to make up the difference. This strategy must be accompanied by ongoing efforts for reduction, however, to ensure that offsetting projects aid in the process of actually decreasing emissions overall. This LCM and offsetting approach to tourism is countered by another idea that a more holistic paradigm shift is required to have widespread effectiveness in decarbonizing the industry.

The goal of this study was to envision a proof-of-concept at a small event, for which current research has been limited. This concept demonstrates a feasibility for similar events or other ecotourism enterprises, particularly in the design and developmental phases. Continued propagation of these principles will allow for expansion in events with higher capacity of participants or spectators, tourism stakeholders with larger reach, or other municipalities which host such enterprises. Crafting and improving upon this framework will allow for continued engagement and education of communities both small and large. As most events are not exceptionally large in nature, application at the small and meso-scale offers opportunities for community-based initiatives directly. The process here poses an in-depth analysis for ecotourism stakeholders to have a more solid understanding of what is currently still in development. Without a ubiquitous standard on LCA techniques, reduction methods, and offsetting strategies, applying these concepts to individual events and ecotourism-focused communities will rely on further research, cooperation among various stakeholders, honest analytical interpretation, and solution oversight.

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# Appendix

## Transportation Survey

The following is the Google Form survey that was sent out to participants who were not originating in Bellingham for their travel to the Ski to Sea event.

# Traveling Towards a Net-Zero Ski to Sea

Traveling to and from this unique event comes with its own impacts, particularly with greenhouse gas emissions. The data from this anonymous survey will be an important piece in determining Ski to Sea's impacts so we can connect the racers with local offsetting measures, both enhancing our community and addressing a side effect of our shared love of moving in the outdoors.

1. From what city, state, and ZIP will you be traveling?

__________________________________

2. How will you be traveling to and from Bellingham?

*Mark only one oval.*

- ◯ Personal vehicle (car, etc) Plane
- ◯ Bus
- ◯
- ◯ Other: __________________________________

3. If you plan on driving, with how many other team members will you *likely* be carpooling?

*Mark only one oval.*

- 0
- 1
- 2
- 3
- 4
- 5
- N/A
- I am not sure
- Other: ______________________

4. If driving, do you plan on driving with a canoe, kayak, bike, or roof box on top of your vehicle?

*Mark only one oval.*

- Yes
- No
- N/A

5. If you are flying to the event, into which city will you be flying?

*Mark only one oval.*

- Seattle
- Bellingham
- Other:

6. What is your flight path? (ie Indianapolis to Seattle direct, Chicago to Bellingham via Seattle, etc)

_______________________________

7. If flying into another city, how do you plan on getting to Bellingham for race day?

*Mark only one oval.*

- Bus/shutt
- le Car
- rental

Friend/family pick-up

- Other: _______________________________

---

8. Optional but helpful: What is the name of the team with which you'll be racing?

_______________________________

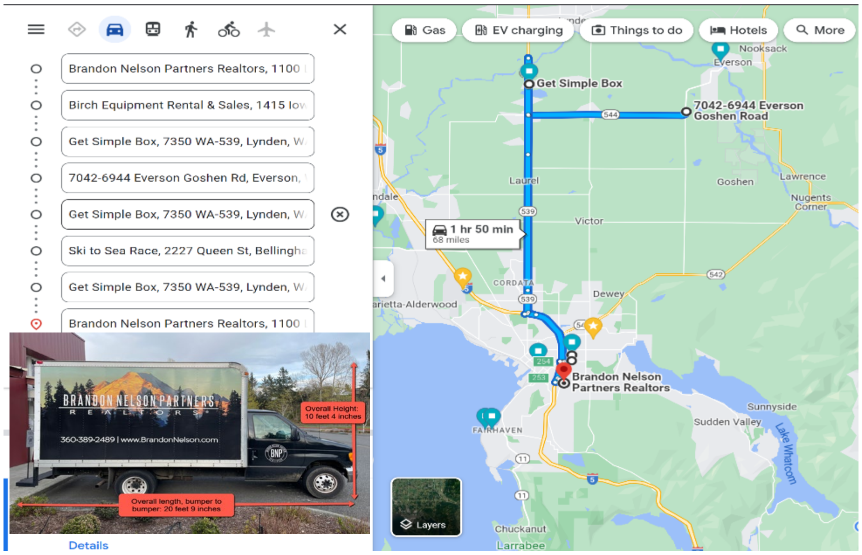
## GoogleMaps API code:

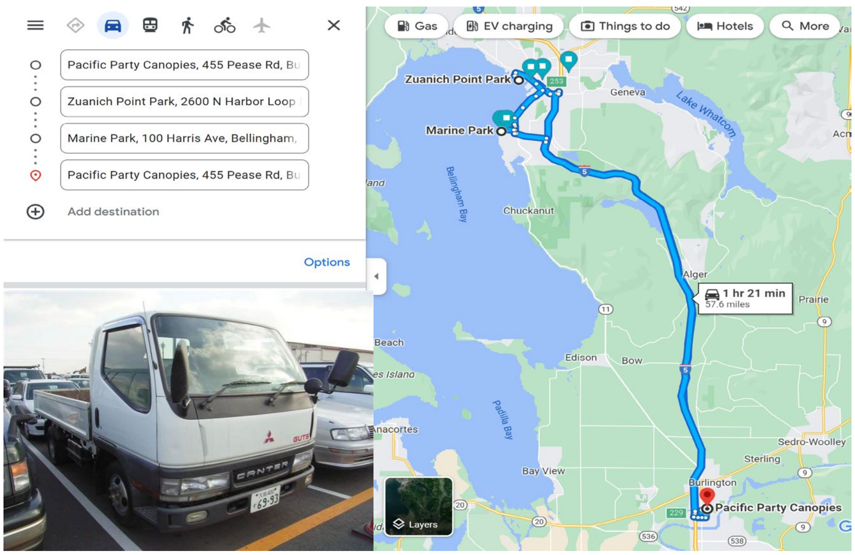
```
install.packages('gmapsdistance')

library(gmapsdistance)

library(stringr)

library(dplyr)
```

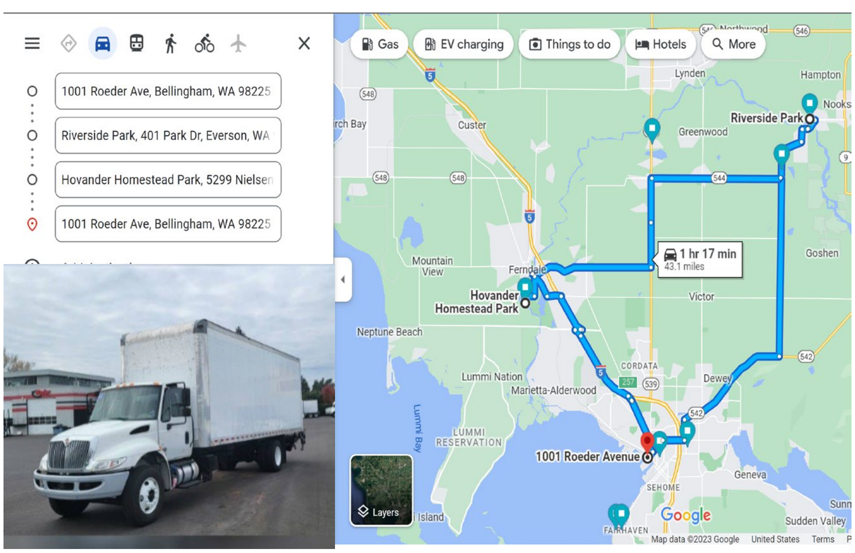
```
drive <- read.csv(file.choose())
combined<-paste(drive$lat,drive$long,sep="+")
head(combined)

drive$start<-c("48.7519+-122.4787")
drive$destination<-combined

origindf<-as.data.frame(combined)
drivingdist <- as.data.frame(gmapsdistance(origin = drive$start,
        destination = drive$destination,
combinations="pairwise",traffic_model="optimistic",dep_time="09:00:00",dep_date="2023-05-
27",mode="driving",
        key="AIzaSyDU-_qZqrgkYFa8lJfRY1MYVkkukiytQIc"))
drivingdist
head(drivingdist)
getwd()
write.csv(drivingdist,'C:/Users/ttarr/OneDrive - Western Washington University/Ski to The(sis)/Final Transport
Calcs/totalemissionsgmaps.csv')
```

# Operations Delivery Routes and Vehicles

The following images show the path and vehicle use for general equipment transfer, Pacific Party Canopy, and Sanitary Services Company.


Brandon Nelson Partners Realtors, 1100
Birch Equipment Rental & Sales, 1415
Get Simple Box, 7350 WA-539, Lynden, W
7042-6944 Everson Goshen Rd, Everson,
Get Simple Box, 7350 WA-539, Lynden, W
Ski to Sea Race, 2227 Queen St, Bellingh
Get Simple Box, 7350 WA-539, Lynden, W
Brandon Nelson Partners Realtors, 1100
BRANDON NELSON PARTNERS
REALTORS
360-389-2489 | www.BrandonNelson.com
Overall Height: 10 feet 4 inches
Overall length, bumper to bumper: 20 feet 9 inches
Details
Gas
EV charging
Things to do
Hotels
More
Get Simple Box
7042-6944 Everson Goshen Road
1 hr 50 min
68 miles
Brandon Nelson Partners Realtors
Layers


Pacific Party Canopies, 455 Pease Rd, Bu
Zuanich Point Park, 2600 N Harbor Loop
Marine Park, 100 Harris Ave, Bellingham,
Pacific Party Canopies, 455 Pease Rd, Bu
Add destination
Options
Gas
EV charging
Things to do
Hotels
More
Zuanich Point Park
Marine Park
1 hr 21 min
57.6 miles
Pacific Party Canopies
Layers


1001 Roeder Ave, Bellingham, WA 98225
Riverside Park, 401 Park Dr, Everson, WA
Hovander Homestead Park, 5299 Nielsen
1001 Roeder Ave, Bellingham, WA 98225
Gas
EV charging
Things to do
Hotels
More
Riverside Park
1 hr 17 min
43.1 miles
Hovander Homestead Park
1001 Roeder Avenue
Layers
Google
Map data ©2023 Google
United States
Terms