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TOURISM ECO-EFFICIENCY THROUGH A MODULAR LENS



SARAH TEIGEIRO
SOPHIE BERNARD
JEAN-MARC FRAYRET

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Tourism Eco-Efficiency Through a Modular Lens

Sarah Teigeiro^{}, Sophie Bernard[†], Jean-Marc Frayret[‡]*

Abstract

The inherent complexity of the tourism industry has led to the emergence of numerous ecolabels or environmental calculators, which frequently suffer from a lack of rigour, transparency, and standardisation, thereby hindering the clear identification of more sustainable offerings. To address these challenges, this study proposes a four-step systematic method for applying a modular multidimensional framework to assess eco-efficiency in tourism systems. By decomposing the complexity of tourism systems into distinct modular components, the framework facilitates a systematic evaluation and flexible configuration with standardised eco-efficiency factors. The framework's versatility is demonstrated through two application perspectives, namely, an outfitter as a hospitality service provider and a tour operator, illustrating how modularity enables the development of flexible eco-efficient scenarios across different levels of the tourism value chain. Using the case of halieutic tourism, the findings suggest that outfitter hospitality services transitioning to renewable energy can support a reduction in their environmental impact. However, they should account for potential shifts in impact and consider demand reduction strategies. From the tour operator's perspective, transportation is the predominant source of impacts in tourism packages. While extending the duration of trips decreases impacts on a per-day basis, it increases overall impacts; thus, assessments should also consider annual travel patterns at the individual level and occupation rates of services consumed. This modular approach holds potential to improve the reliability of tourism calculators or ecolabels by fostering standardization alongside adaptability, providing a robust tool for transparent and effective sustainability certification or other means.

Résumé

La complexité inhérente à l'industrie du tourisme a conduit à l'émergence de nombreux écolabels ou calculateurs environnementaux, qui souffrent fréquemment d'un manque de rigueur, de transparence et de standardisation, rendant difficile l'identification claire des offres les plus durables. Pour répondre à ces défis, cette étude propose une méthode systématique en quatre étapes permettant d'appliquer un cadre modulaire multidimensionnel afin d'évaluer l'éco-efficacité des systèmes touristiques. En décomposant la complexité des systèmes touristiques en composantes modulaires distinctes, ce cadre facilite une évaluation systématique ainsi qu'une configuration flexible reposant sur des facteurs d'éco-efficacité standardisés.

^{*}Department of Mathematics and Industrial Engineering, Polytechnique Montreal,

[†]Department of Mathematics and Industrial Engineering, Polytechnique Montreal ; Interdisciplinary Research Centre for Operationalization of Sustainable Development ; Chercheuse et Fellow CIRANO

[‡] Department of Mathematics and Industrial Engineering, Polytechnique Montreal ; Interdisciplinary Research Centre for Operationalization of Sustainable Development

La polyvalence du cadre est démontrée à travers deux perspectives d'application : celle d'un pourvoyeur en tant que prestataire de services d'hébergement, et celle d'un voyageur. Cela illustre la manière dont la modularité permet de développer des scénarios éco-efficaces flexibles à différents niveaux de la chaîne de valeur touristique.

En prenant le cas du tourisme halieutique, les résultats suggèrent que les services d'hébergement des pourvoyeurs qui adoptent les énergies renouvelables peuvent contribuer à réduire leur impact environnemental. Toutefois, ils doivent tenir compte des possibles transferts d'impact et envisager des stratégies de réduction de la demande. Du point de vue du voyageur, le transport constitue la principale source d'impacts dans les forfaits touristiques. Bien qu'un allongement de la durée des séjours réduise les impacts rapportés à la journée, il augmente les impacts globaux ; les évaluations devraient donc également prendre en compte les habitudes annuelles de déplacement à l'échelle individuelle ainsi que les taux d'occupation des services consommés.

Cette approche modulaire présente un potentiel pour améliorer la fiabilité des calculateurs touristiques ou des écolabels en favorisant à la fois la standardisation et l'adaptabilité, offrant ainsi un outil robuste pour une certification durable transparente et efficace, ou pour d'autres dispositifs similaires.

Keywords/ Mots-clés : Tourism sustainability, Eco-efficiency, Modularity, Ecolabels, Service design, Life cycle assessment (LCA) / durabilité du tourisme, éco-efficacité, modularité, écolabels, conception de services, analyse du cycle de vie (ACV).

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1. INTRODUCTION

Despite the pandemic, international tourist arrivals surpassed pre-2019 levels in early 2024 (ONU Tourisme, 2025), indicating continued growth toward the target of 1.8 billion arrivals by 2030 (UNWTO, UNEP, 2019). This expansion increases pressure on natural resources, highlighting the urgent need to keep tourism within planetary boundaries for survival (Eijgelaar & Peeters, 2024). Tourism is a complex system offering diverse service design opportunities, from mass customisation to on-demand personalization, yet this challenges sustainability assessment. It is a heterogeneous network of actors, including governments, destination managers, tour operators and suppliers, that requires a comprehensive, integrative framework capturing multiple perspectives, scales, space and contexts to evaluate and enhance sustainability effectively (Gössling et al., 2023).

Eco-efficiency in this framework requires coordinated stakeholder efforts across different system levels to modify consumption patterns, delivering equal or greater value with reduced environmental impacts that align with planetary limits (WBCSD, 2006). Assessing sustainability at tourism destinations is inherently complex and often demands combining tools to support comprehensive evaluation and informed decision-making. The literature typically evaluates tourism activities and sectors independently due to their inherent complexity, whereas the complexity of tourism packages necessitates assessment tools that provide more nuanced insights than industry-level evaluations (Becken et al., 2003; Filimonau, 2016). On the other hand, ecolabels and certification schemes generally lack transparency (Fernandes Martins et al., 2022; Wang & Su, 2022) and the identification of reliable alternatives for tourism package design. Tourism would benefit from a standardized yet adaptable sustainability evaluation approach that integrates stakeholder perspectives and relevant dimensions. This gap underscores the need for further research into mechanisms for effectively integrating sustainable performance (Wang & Su, 2022).

To address complexity in design and production, engineering and information technology have adopted modular approaches. A. Bask et al. (2011) mention that modularity reduces strong interdependencies among components sharing common features, enabling flexible combination, substitution, or modification without disrupting the system architecture. It also facilitates product variations in function, characteristics, and performance. Campagnolo and Camuffo (2010) highlight the contribution of modularity to ensure flexible system extension and iteration without redesign, thereby preserving module autonomy. The literature discusses the application of modularity in product development, production, and supply chains (Avlonitis & Hsuan, 2017; A. Bask et al., 2010, 2011; A. H. Bask et al., 2010; Brax et al., 2017; Micheli et al., 2019; Pekkarinen & Ulkuniemi, 2008). In contrast, modularity in service systems remains less explored. Notable studies include de Mattos et al. (2021), which reviews service modularity concepts, effects, enablers, and methods, Eissens-vander Laan et al. (2016), examining how modularization and service routines influence decomposition logics; and Voss and Hsuan (2009), highlighting the role of modularity in service design and innovation for competitiveness.

While studies in the field of engineering and management address modularity in product systems that support sustainability by improving eco-efficiency and design performance (Groetsch et al., 2021; Gu et al., 1997; Sonogo et al., 2018; Spykman et al., 2021), research on modularity and sustainability in service systems is scarce. Wehner et al. (2020) show modularity in household waste logistics enhances energy efficiency, and Teigeiro et al. (2025) discuss modularity's potential for standardizing sustainability information in tourism. Tourism modularity research primarily targets personalisation, standardisation, and competitiveness (Avlonitis & Hsuan, 2017;

Del Vecchio et al., 2018; Voss & Hsuan, 2009). To date, no study has explicitly applied the concept of modularity to sustainability assessment in complex tourism services.

This study addresses this gap by demonstrating how modularity can standardise sustainability measurement in service industries, particularly tourism, improving communication and decision-making. It has two objectives: 1) to propose and apply a systemic and systematic method to characterise a modular tourism system for sustainability, based on the modular conceptual modelling framework by Teigeiro et al. (2025). This framework guides modular modelling of the tourism system, suitable for different perspectives, sustainable dimensions, resources, and sustainability evaluation tools. 2) To demonstrate the method's relevance to apply a flexible calculation framework based on Teigeiro et al. (2025) general equation, enabling absolute environmental performance scales across the tourism supply chain. Essentially, this study presents the back-end work to operationalize a framework for sustainable production and consumption, complementing the framework proposed for tour operators by De Camillis et al. (2012). The method is illustrated via the example of a halieutic tourism case study to analyse two perspectives: (1) the outfitter as a hospitality service provider with energy source scenarios, and (2) a tourism package including accommodation and transportation, offered by a tour operator, as a travel organiser. The approach produces independent, well-defined modules that form a flexible modelling framework, allowing for the reuse, addition, removal, and modification of modules within or across different perspectives. As one type of application, this structured flexibility enabled the creation of 25 distinct tourism package scenarios derived from diverse module inputs, all comparable in terms of sustainable criteria performance and eco-efficiency.

By structuring environmental impact measurement through modularity, tourism modules and their sustainability evaluations can be standardized, harmonized, and used with flexibility and efficiency. This enhances identification of sustainable options and improves the reliability of communication tools such as ecolabels. The approach is intended for labelling organizations, government agencies, and researchers seeking to integrate standardized sustainability metrics into tourism certification and advance the role of modularity in service sustainability.

1. METHOD

The systematic method proposed in Figure 1 facilitates the systemic modelling of the tourism sector for distinct stakeholders by breaking down complexity into manageable and independent modules and supports the identification of sustainability improvements. It allows, for instance, consumers to consider eco-efficiency choices for products and services, suppliers to opt for sustainably sound technologies or resources, or investors to select eco-efficient destinations for their tourism projects. Drawing from the modularity methods phases in the literature (de Mattos et al., 2021; Eissens-van der Laan et al., 2016; Groetsch et al., 2021; Gu et al., 1997; Spykman et al., 2021; Voss & Hsuan, 2009), the proposed method includes four (4) consecutive steps (Figure 1) to operationalise the modular modelling framework of tourism sustainability by Teigeiro et al. (2025). The method is also inspired by the Deming cycle, also known as the plan-do-check-act cycle (PDCA), for its continuous improvement approach (Johnson, 2002). Step 1 defines a system model and then Step 2 decomposes its complexity into manageable modules, defining the module alternatives and their relations. The definition of these steps represents the core contribution of this study. Step 3 provides an adaptive approach to creating and assessing scenarios, utilising modular strategies. Step 4 involves interpreting the results and making decisions. The method leverages modularity to model tourism systems, enabling flexible adjustments without altering the system's

structure, supported by the standardization inherent to modularity (Langlois, 2002). These adjustments can be adding, removing, swapping, reusing and scaling modules. For example, swapping hotel rooms or changing hotel choices during a trip, changing the destination, or adopting alternative transportation modes to improve the overall environmental impact, while maintaining an equivalent or comparable experience. While the primary contribution of this study lies in defining steps 1 and 2, the authors further illustrate the configuration of both systems using empirically derived eco-efficiency results. Data for both perspectives were collected from May to September 2022 through on-site and off-site interviews, observations, measurements, consumption estimates, calculations and data from ecoinvent 3.6 database.

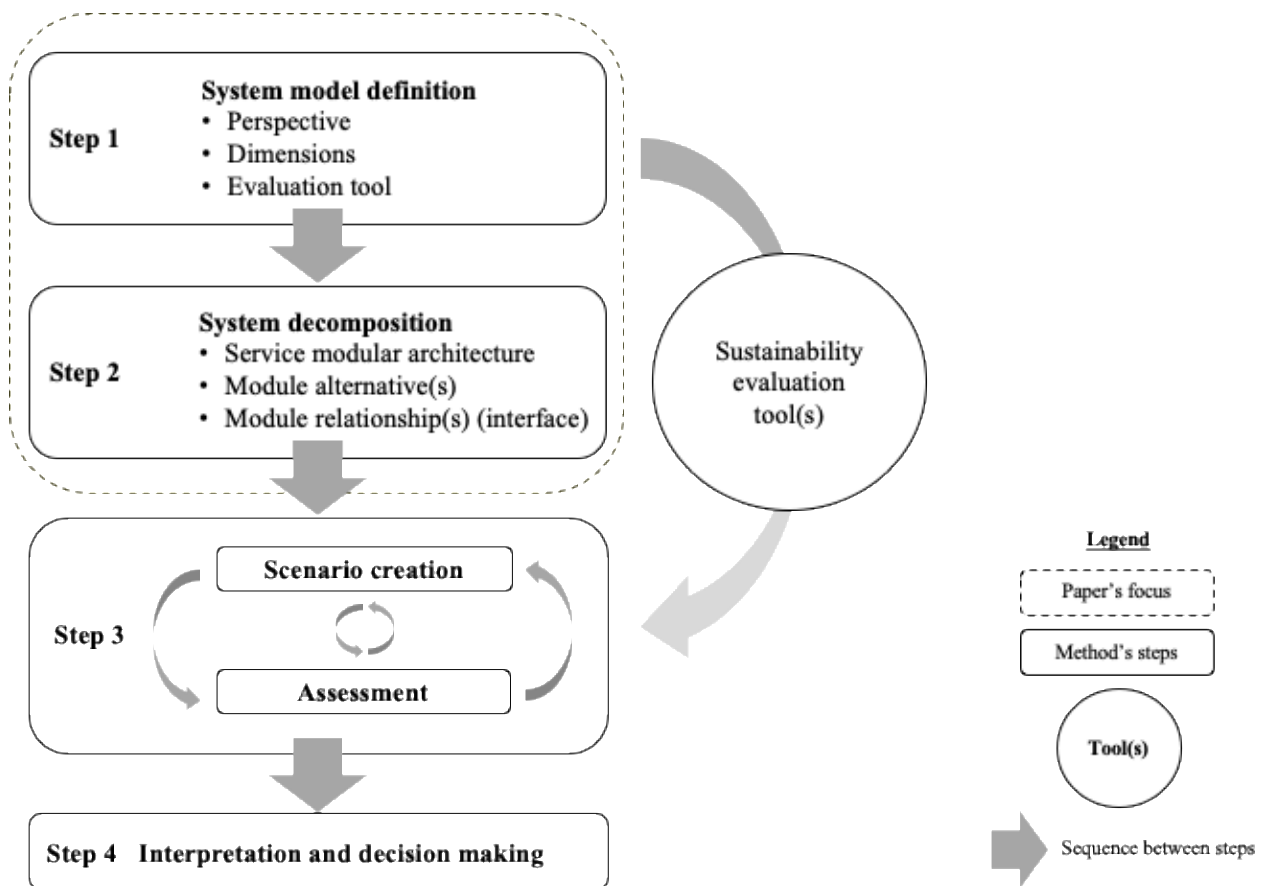


Figure 1 The systematic method for service modular modelling

Step 1_System model definition

This step defines two preliminary points for configuring and evaluating the tourism system: the perspective and dimensions. The perspective designates the point of view from which the system is modelled (e.g., government, industry, service provider, tour operator, product or service, or consumer). This situates the system within the tourism ecosystem, which will influence the structure of the modular system based on the scope of action for improved sustainability.

The system dimensions are specified by anticipating the choice of evaluation tool(s) to be used (Teigeiro et al., 2025). They refer to the scale (e.g., geographic, economic), the scope (e.g., technosphere, ecosphere, sociosphere and dynamic effects) and the temporal aspects (e.g., duration, prospective, retrospective). The sustainable objectives to be pursued are part of the scope (e.g., environmental, social, cultural, economic and technological performance). As mentioned by Spykman et al. (2021), “ (...) the results are sensitive to methodological choices: thus, these should be carefully communicated during the modular assessment system modelling.”

The choice of tool or combination of tools is facilitated once the system specifics and dimensions are defined, once the study’s angle has been established (Schianetz et al., 2007). The selected tool(s) also dictate the indicators for the system analysis, and a combination of tools may be appropriate for a comprehensive evaluation (step 3) and to satisfy ecolabel indicators. Tool selection must account for challenges related to usability, required expertise, data accessibility and collection, and associated evaluation costs.

Step 2_System decomposition

This step aims to describe the system’s modular architecture, analyse the modules, their alternatives, and relationships within a tourism system. First, the decomposition step visualizes the system’s structure from the perspective defined in step 1, using the service modular architecture levels proposed by Voss and Hsuan (2009), four (4) service architecture levels were adapted to the tourism industry based on the modelling framework (Table 1). The latter allows us to adapt the module structure to various perspectives, service offers, and consider resources required as part of the architecture, thereby enhancing it from a sustainability standpoint. The system architecture levels can be represented by a tree diagram, accompanied by a module descriptive sheet, which is presented later. Then, module definition entails delineating its boundaries, specifying its purpose or objective, identifying included components, and outlining alternative configurations with their respective conceptual distinctions.

Finally, the relationships (interface) are defined by the level of dependence between modules, which should be minimised to obtain greater modularity (Eissens-van der Laan et al., 2016). Defining relationships also requires defining module units or component units (considered the smallest unit in modularity (de Mattos et al., 2021), which should be coherent amongst module categories. The unit definition is necessary to ensure uniformity, allowing comparison, replication, combination and/or module scaling to configure scenarios. Description sheets can help keep a record of module descriptions and highlight any differences they may contain.

Table 1 Service modular architecture levels (adapted from Voss and Hsuan [2009] and Teigeiro et al. [2025])

0. Industry

1. Service provider/ supply chain

2. Product and service package (one or many products/services offered by many service provider)

3. Product and service composite or bundle (one or many products and services offered by one service provider)

4. Product and service component

5. Resource

Step 3_ Scenario creation and assessment

This step offers an adaptive approach composed of two (2) operations: first, by configuring scenarios, which can then be improved following the module or system sustainability assessment. As part of this step, sensitivity analysis and optimisation can be performed to evaluate changes in tourism sustainability factors or improve results.

Scenario creation at the module level involves alternative module configurations that are evaluated independently of the system but will influence its overall performance. At the system level, module configuration, based on its performance, also influences the system's performance. Seamless configuration and comparison of alternative scenarios assume they are evaluated using coordinated units of conversion and sustainability evaluation tools. This operation consists of following the method for the evaluation tool(s) selected that correspond to the sustainability objectives identified in step 1. Tourism is mainly intangible, centred on experiences that are emotional, sensory, or cognitive rather than material. Nevertheless, these experiences are enabled by tangible modules, such as transportation, accommodation, energy, and infrastructure. Some modules are concrete and directly chosen by tourists, while others operate in the background and remain less visible, especially given the service-oriented nature of the industry. Even the most abstract aspects of tourism are underpinned by concrete resource modules that make them possible, such as a walking tour given by a tour guide.

Eissens-van der Laan et al., (2016) propose six (6) service modularity strategies that offer options to combine and interchange modules, supporting scenario creation in addition to the baseline scenario: share (reuse), swap, cut-to-fit (modify on the fly), mix (predefined options), bus (add/increase and/or remove/reduce), sectional (unlimited combinations). These strategies are addressed as tourism eco-efficiency drivers (factors) in Teigeiro et al. (2025) (Table 2) and support the creation of scenarios. By adjusting the four (4) main factors, a baseline scenario can be adapted and scaled to the proper system service modular architecture level of the perspective. The factors are inspired by the IPAT equation (Font Vivanco et al., 2014) and address the volume of tourists, the consumption level per tourist and tourism basket, resource efficiency in terms of resources per product and service, and the impact per resource and impact categories. One or many factors can be addressed to create new scenarios. Tourism baskets represent selected modules to analyse and evaluate, such as tourism packages (trips) or any other specific tourism offers, including hospitality services or transportation, along with their associated resources. System or module scenario creation can be iterative and, therefore, may require adjustments after its evaluation.

Table 2 Tourism eco-efficiency factors by Teigeiro et al. (2025)

Factors	Volume	Consumption level (affluence)		Resource efficiency (technology)		Characterisation factor (CF)
Matrix (or vector)	V	A	B	P	R	F
Parameters	[1*1]	[1*q]	[q*a]	[a*d]	[d*b]	[b*j]
Tourism factors	Tourists	$\frac{\text{Touristic baskets}}{\text{Tourist}}$	$\frac{\text{PSS}}{\text{Touristic basket}}$	$\frac{\text{Resources}}{\text{PS}}$	$\frac{\text{Impacts}}{\text{Resource}}$	$\frac{\text{Damage category CF}}{\text{Impact}}$

Step 4 Interpretation and decision-making

Results are interpreted to determine the preferred system modular configuration, focusing on improving sustainability performance or a specific sustainability objective, such as eco-efficiency. These can also consider scenarios that best fit preferences, including quality, comfort, budget, or policies. The scenario results are presented in absolute scales or relative values, based on the evaluation approach and the study’s objective. Results can also be normalised to facilitate comparison and interpretation. This proposed methodology is demonstrated in the remainder of the paper through its application in representing tourism systems and services, from two distinct perspectives: a hospitality service provider and a tour operator involved in creating tourism packages. We then propose an adaptable calculation framework for creating absolute scales to evaluate environmental performance.

2. APPLICATION

The study’s research site is located at Réservoir Gouin, Québec, Canada, a typical halieutic location in the Mauricie region of Quebec. Halieutic tourism typically takes place in natural, secluded settings with basic amenities, where fishing is the main activity. While Quebec meets 46 % of its energy needs entirely from renewable sources (Whitmore & Pineault, 2024), outfitters still rely on fossil fuels, and little data exist on the environmental impact of this tourism niche to support sustainable¹ alternatives.

Within this context, the study explores two perspectives that are presented successively at each step: the outfitter as a hospitality service provider, and the tour operator as a travel organiser. Energy use is the principal focus, with modularity offering flexibility to measure environmental impacts through alternative compositions and configurations. The outfitter perspective models the hospitality services (modules) energy eco-efficiency from an organisational level. The tour operator’s perspective assembles eco-efficient tourism packages by integrating evaluated accommodation and transport services (modules) under different scenarios and tourism factors values proposed by Teigeiro et al. (2025).

Step 1 System model definition

The first system perspective modelled is that of a hospitality service provider system of the Outfitter type (Table 3). Its sustainable objectives are to improve its climate change footprint performance and overall eco-efficiency, reduce its dependence on fossil fuels, logistics costs, and

¹ The authors recognise that no sustainable tourism offers are sustainable per se, but their status can be improved or become more sustainable than another.

risks associated with potential spills. The measure considered by the organisation, is through energy source and technology change. Therefore, it wishes to evaluate the ideal independent energy source alternative from an environmental eco-efficiency standpoint. Specifically, the scope encompasses interactions between the technosphere and ecosphere, involving both natural environments and manufactured solutions. The life cycle assessment (LCA) approach is a suitable environmental evaluation tool for comparing alternative technological solutions over their entire life cycles in this context. It provides visibility into potential trade-offs and hotspots and is also widely used in environmental product declarations and ecodesign activities (Saadé & Jolliet, 2024).

The second perspective modelled is the tour operator’s system, which typically develops tourism packages by selecting products and services from service providers (Table 3). Tour operators can influence and promote sustainable consumption (Sigala, 2008) to reduce negative environmental impacts that extend beyond their own operations by influencing suppliers and customers (Budeanu, 2005). This example demonstrates one approach by proposing a range of tourism package scenarios and their environmental performances, based on energy requirements. It is done by assembling variants of the outfitter and transportation services modules. To accomplish this, service modules need to utilize common structures and evaluation tools that will be presented in the following steps, enabling tourism factors to scale appropriately (using the tourism factors proposed by Teigeiro et al. (2025)).

Table 3 System model definition

Perspective	Sustainable objective	Dimension	Evaluation tool
<p>Outfitter hospitality service provider</p> <p>Service provider (service modular architecture level 1)</p>	<p>Identify and compare the environmental impacts of alternative energy sources for the outfitter’s installation operations. This allows for eco-efficiency performance improvement on the market, reduction of fossil fuel dependence, logistic costs, and risks.</p>	<p>Sustainability scope: Technosphere and ecosphere.</p> <p>Economic scale: organisation level.</p> <p>Temporal relationship: Retrospective based on past data.</p>	<p>Life cycle assessment method (LCA) is suitable for evaluating the impacts of alternative technologies.</p>
<p>Tour operator</p> <p>Product and service package by travel organiser (service modular architecture level 1)</p>	<p>Assemble hospitality and transportation services modules available on the market to create tourism package scenarios and compare their environmental performance in terms of energy consumption.</p>	<p>Sustainability scope: Technosphere and ecosphere.</p> <p>Economic scale: organisation level.</p> <p>Temporal relationship: Retrospective based on past data.</p>	<p>Idem. Assembling modules using the LCA method and scaling modules to create packages with sustainable tourism factors.</p>

Step 2_System decomposition

To decompose the first perspective of the Outfitter's hospitality service and pursue its sustainability objective, the service modular architecture establishes a baseline for identifying the services to be studied within their context (Figure 2). Module shading and contours are used to determine the relationships between modules and to identify inclusions or exclusions. On-site activities are present but omitted from the analysis to maintain focus on essential hospitality-related services. Within the service bundle, dependency relationships are drawn based on the nature of the modules. For instance, on-site transport and activities modules are optional, and illustrated by dashed modules, and could be easily removed or added to the structure. On-site transport is included in all scenarios with fossil fuel, while activities are excluded from the system modelled. On the other hand, accommodation and restaurant services are provided by default due to the site's isolated nature. Modules offering alternative options for the system's objective are highlighted with a bold contour at the resource level, encompassing both manufactures and natural resources utilised by the service system.

The energy type and energy equipment resource modules alternatives for the accommodation and restaurant services will be studied to evaluate the extent to which they influence the system's sustainability objective of eco-efficiency performance. These resource modules may have dependencies, as the equipment may change, including the necessary equipment associated with it and other equipment, such as more energy-efficient appliances (e.g., propane to electric appliances). One needs to be aware of potential dependencies, although modularity aims for independence between modules. The energy resources of fossil fuel (status quo), solar and wind energy and their associated equipment will be evaluated under different scenarios and compared. The components and resource identification within the supplier service bundle provide more granularity to the system composition, allowing for the definition of each module's scope, its sustainable objective contribution, potential variants, units, and specifics (Table 4, Figure 3). To address nonlinearity issues that arise with varying occupation rate, it is helpful for a module to hold two defining units, one to calculate results on an annual basis and the second to level average results at the smallest unit based on annual occupation, such as person.night in the case of the outfitter hospitality services. This approach also allows for extrapolating module results to different perspectives with limited data, using proxy data for instance. In addition, this study uses consumption and production units to facilitate comparisons over time and across contexts, rather than dividing the impacts by monetary value (Gössling et al., 2005).

The tour operator's perspective decomposition identifies tourism package bundles of products and services, along with their components and market alternatives that could influence the package's eco-efficiency performance Figure 4. In this example, the tourism package comprises a hospitality services bundle and transportation to the site at Reservoir Gouin. In the case of a tourism package with multiple destination cities, the tourism package could be separated by city or day. The combinations of market module options by the tour operator could provide eco-efficient performances if data is available. Each outfitter hospitality services option identified offers the standard service objectives of shelter, food preparation, and on-site transportation, with different distinct energy technology profiles (Table 5, Figure 5). As modularity seeks independence between modules, the creation of a tourism package respects this condition as distinct suppliers can offer each module and can be personalised. Each module operates independently, but a certain level of interdependence is required for a complete and seamless tourism experience. For example, transportation to the site is independent of the outfitter's

hospitality services, however, transportation to the site is necessary to access the accommodations. Whatever the type of transport (e.g., mode), it is required as part of the tourism package to be consumed; however, the more diverse and available the offers are, the more transportation can find independence in practice and reduce the risk of operational disruption. The variants possible for this destination are by land with an SUV-type vehicle, by boat for the last kilometres, or by helicopter. To gather the necessary information and details, a module description sheet (outfitter hospitality services and transportation options as outlined in Table 6 and Table 7, respectively) is used to include the module attributes, which will facilitate data gathering to support system scenario evaluation (step 4). The module description sheet can also be used for similar purposes as the food nutritional facts label, without the environmental information, which is what this study could add.

By structuring, defining, and analyzing the perspective's service modules, objectives, relationships, and specificities, we can model the system at each level and identify the distinct sustainable levers adapted to each service modular architecture level.

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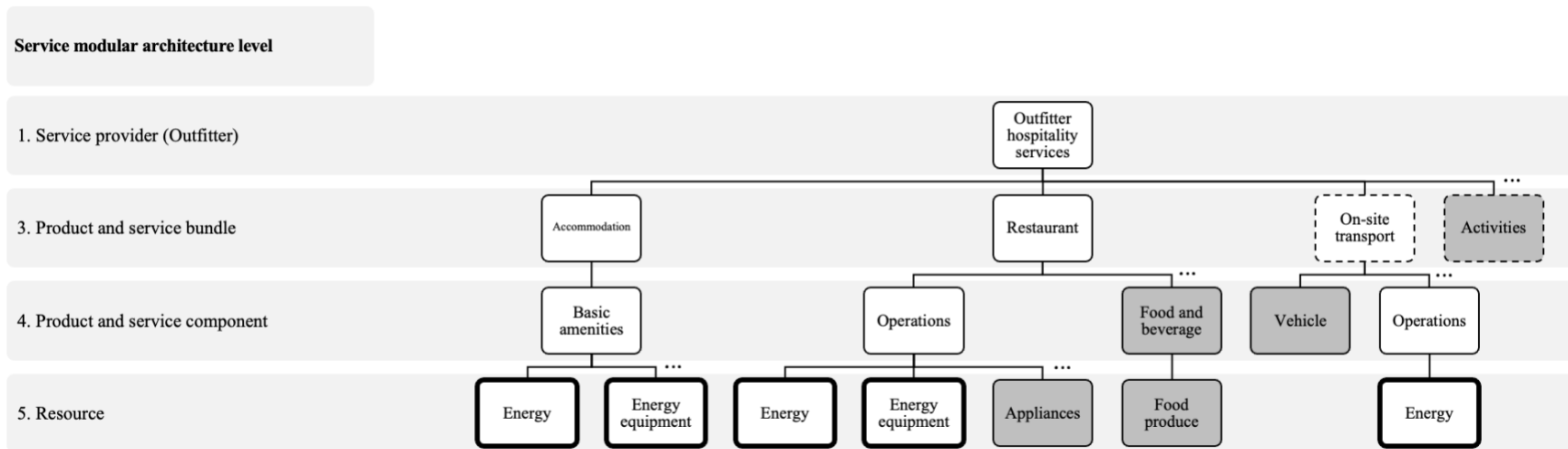


Figure 2 Outfitter hospitality services decomposition

Table 4 Modules definition for outfitter hospitality services

	Service module			
	Outfitter hospitality services	Accommodation	Restaurant	On-site transportation
Service modular architecture level	Level 1: Service provider	Level 3: Product and service bundle	Level 3: Product and service bundle	Level 3: Product and service bundle
Module definition	On-site service to visitors by offering service a bundle of accommodation, restaurant and on-site transportation.	Module is equipped with basic amenities including housekeeping (sheet cleaning), lighting, heating, potable water, waste management, and internet.	Module includes operations (food preparation, cooking, storage, and cleaning with dishwasher).	Module's objective is to transport visitors upon arrival and departure, with equipment. The

Service module				
	Outfitter hospitality services	Accommodation	Restaurant	On-site transportation
		The main objective is to offer shelter to visitors.	The primary objective is to provide three meals a day to visitors.	fossil fuel variant is included as default option.
Sustainable objective	Offer a performing eco-efficient services by evaluating alternative energy sources.	Offer a performing eco-efficient accommodation basic amenities by evaluating alternative energy sources.	Offer a performing eco-efficient restaurant operation by evaluating alternative energy sources.	None

Tourism Eco-Efficiency Through a Modular Lens

Table 4 Module definition for outfitter hospitality services (cont'd and end)

Service module				
	Outfitter hospitality services	Accommodation	Restaurant	On-site transportation
Module alternative	Based on the energy source and its equipment. Outfitter variants based on energy resource scenarios studied: fossil fuel (status quo), solar (photovoltaic), wind turbines.	The energy resource consumed offer the basic amenities. The energy type and its equipment variants studied are fossil fuel (status quo), solar (photovoltaic), wind turbines.	The energy resource consumed offers restaurant operations to take place and the energy type and its equipment variants to be studied are fossil fuel (status quo), solar (photovoltaic), wind turbines.	None
Module unit	Per year Person.night	Per year Person.night	Per year Person.night	Per year Person.night
Module specifics	Composed of accommodation, restaurant and on-site service bundle. Accommodation and restaurant energy sources are dependent (visitors have no other option) and on-site transport is optional but usually consumed upon arrival and departure.	The site is open from May to September (105 days a year). The last kilometres to the site are accessible only by boat or helicopter. The sleeping capacity is 2310 person.day. All rooms are equal.	Similar to accommodation, since it is located within the accommodation installation, and it is dependent on accommodation visitors, as each visitor eats at the restaurant by default. The energy consumed by the restaurant operations is shared with the accommodation, therefore it uses the same equipment, variants and units.	All-terrain vehicles are used

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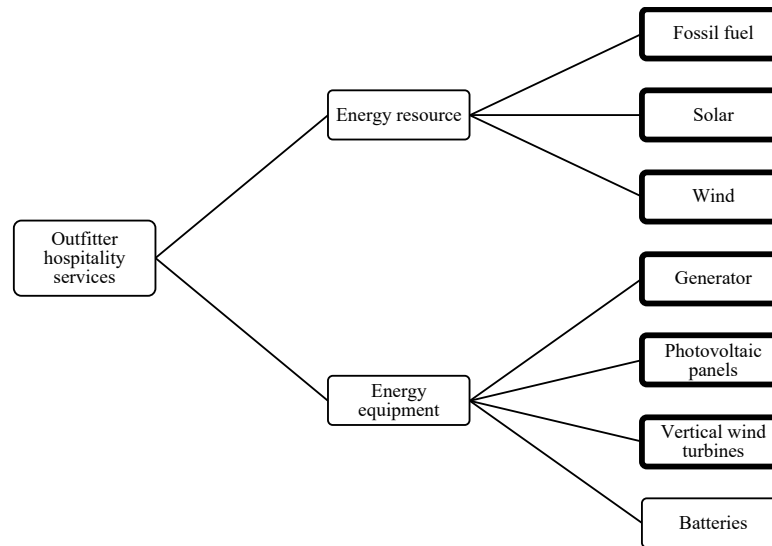


Figure 3 Outfitter hospitality services module variant

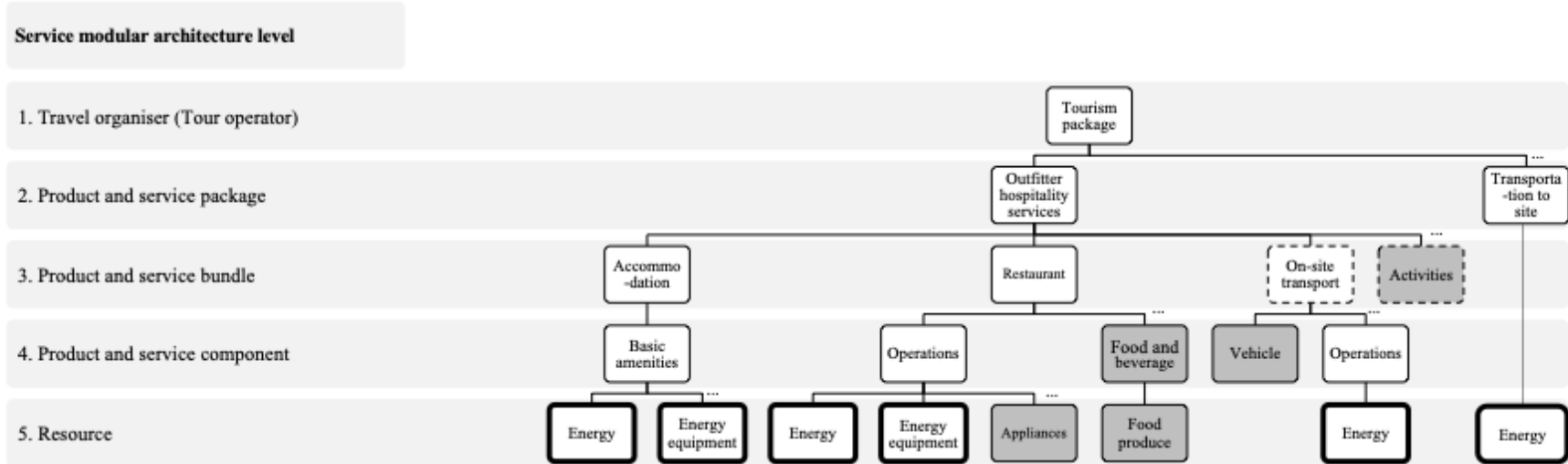


Figure 4 Tour operator tourism package decomposition

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Table 5 Definition for a tour operator tourism package

	Service module		
	Tourism package	Outfitter hospitality services	Transportation to site
Service modular architecture level	Level 1: Travel organiser	Level 2: Product and service package	Level 2: Product and service package
Modules definition	The tourism package offers a tourism experience by providing a combination of outfitter hospitality services and transport to the site.	Includes accommodation, restaurant and on-site transportation. The three modules are considered standard as part of the outfitter hospitality services bundle.	Provides transportation to and from the site, modelled from a fixed departure point, with transfers, to the destination's main site.
Sustainable objective	Offer a performing eco-efficient package by evaluating alternative scenarios formed of alternative service bundles and composite services, based on visitor preferences.	None	None
Module alternative	Outfitter hospitality services (deluxe and basic cottages) and to-site transportation (land, water and air) alternatives available.	Market options to select from their eco-efficient performance based on the energy source and its equipment. Variants range from various combinations of energy sources including fossil fuel (status quo), solar (photovoltaic), and wind turbines.	A combination of land and water transportation modes, or by land and air.

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Table 5 Definition for a tour operator tourism package (cont'd and end)

Service module			
	Tourism package	Outfitter hospitality services	Transportation to site
Module unit	Tourism.package Person.night Km (from Montreal hub to the Réservoir Gouin destination)	Annual Person.night	Person.km (from Montreal hub to the Réservoir Gouin destination)
Module specifics	Composed of a variety of services and configurations using tourism eco-efficiency factors and modular strategies.	Composed of accommodation, restaurant and on-site service bundle. Accommodation and restaurant energy sources are dependent (visitors have no other option) and on-site transport is optional but usually consumed upon arrival and departure.	The last kilometres to the site are only accessible by boat or helicopter. The transportation to site model departs from Montreal and arrives at the Réservoir Gouin site. Land transport to the airport is included from Montreal. Helicopter transport assumes an empty return upon drop-off, as opposed to a boat trip that picks up visitors upon drop-off.

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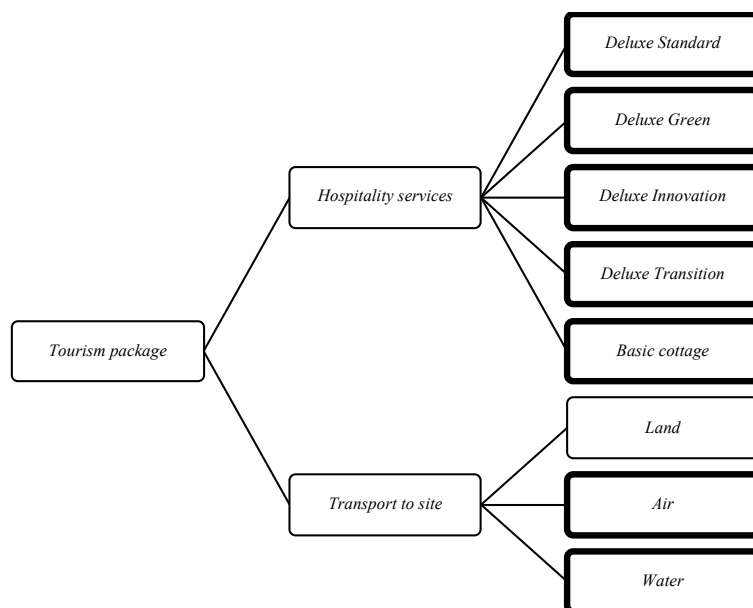


Figure 5 Tour operator tourism package module variants

Table 6 Detailed description sheet_Outfitter hospitality services

Outfitter hospitality services module options					
	Deluxe Standard	Deluxe Green	Deluxe Innovation	Deluxe Transition	Basic Cottage
Localisation	Réservoir Gouin	Réservoir Gouin	Réservoir Gouin	Réservoir Gouin	Réservoir Gouin
Energy profile	99 % Fossil fuel energies < 1% renewable energy	92 % Renewable energies 8 % fossil fuels	Mix 66 % fossil fuels 33 % renewable energies	Mix 66 % fossil fuels 33 % solar energies	Mix 1 % fossil fuels 99 % renewable energies
Energy technology profile	99 % fossil fuels (36 % diesel and 55 % propane, 9 % gasoline), <1 % solar	92 % renewable (50 % solar and 50 % wind), 8 % gasoline	68 % fossil fuels (93% propane, 7 % gasoline), 32% renewables (50 % solar and 50% wind)	68 % fossil fuels (93% propane, 7 % gasoline), 32 % solar	1 % propane, <1 % gasoline, <1 % solar, 98,8 % wood

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Energy equipment	Generator, photovoltaic panels, batteries.	Photovoltaic panels, vertical wind turbines, batteries.	Generator, photovoltaic panels, vertical wind turbines, batteries.	Generator, photovoltaic panels, batteries.	Propane bottles, photovoltaic panels, batteries, wood stove.
Description/ Inclusion	2 stars	2 stars	2 stars	2 stars	1 star
Capacity (person.day)	2 310	2 310	2 310	2 310	735
Occupation rate (2022)	74%	74%	74%	74%	42%

Accommodation star system:

1 star: Running hot water, lighting, heating, kitchen appliances, fire camp, on-site transport.

2 stars: Running hot and filtered water, lighting, heating, restaurant, laundry services, internet, fire camp, on-site transport.

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Table 7 Detailed description sheet_Transportation options

Transportation module options					
	Vehicle type	Maximum capacity	Distance (one-way km)	Route type	Departure to destination
Option 1					
Land transport	SUV vehicle (model X)	4	140	Transit	Montreal (YUL) to Mont-Tremblant (YTM)
Air transport	Helicopter transport (model Y)	4	241	One-way	Mont-Tremblant (YTM) to Outfitter site (Reservoir Gouin) (round trip for pilot)
Option 2					
Land transport	SUV vehicle (model X)	4	527	One-way	Montreal (YUL) to Réservoir Gouin meet up point
Water transport	Boat (model Z)	4	25	Transit	Réservoir Gouin meet up point to Outfitter site

Step 3_ Module assessment and scenario creation

For both perspectives, this step begins with configuring scenarios, followed by their assessment using an evaluation tool to enable informed decisions. The iterative nature of this step allows continuous improvement of the configuration of scenarios based on sustainable criteria (e.g., environmental, social, and economic), as well as other criteria such as preferences (e.g., comfort, security, quality), beyond the environmental indicators addressed in this study. Modular strategies are applied, along with tourism eco-efficient factors (Table 2), used as parameters to create scenarios. In addition to applying modular strategies within perspectives, it has also allowed for the reuse of data across modular architecture levels with unit conversion from annual to person.night units, demonstrating the usefulness of modularity and standardisation.

To ensure methodological consistency, the results for the chosen examples were derived in accordance with Life Cycle Assessment (LCA) principles, while acknowledging that the application of LCA is secondary to this study. The LCA was deployed using the four-step methodology proposed by ISO (Saadé & Jolliet, 2024) and the IMPACT World+ method, which is regionalised globally (Bulle et al., 2019). The ecoinvent 3.6 database, in addition to public information, data collected on-site, and data gathered through interviews, was the primary source of data. The results provide two levels of indicators: for problems related to environmental impacts (midpoint impacts) and for damages representing the potential consequences of these problems on human health and ecosystem quality, described as an area of protection (AoP). Human health is measured in DALY units, which represent the healthy life years lost due to disease or health conditions. Ecosystem quality² is measured in m2 PDF.m2.yr, meaning the potential disappearance fraction of all species on a surface in m2 over a year. Three (3) indicators are put forward amongst 18 existing midpoint impact category indicators: fossil and nuclear energy use in MJ deprived and mineral resources use in kg deprived (resource depletion caused by engaged activities), and climate change – short term in kg CO2 eq (i.e., GWP100). The latter is used as a standalone indicator for carbon footprint (as proposed by the ISO/TS accounting methodology 14067:2018 (Bulle et al., 2019)) for greater visibility on this issue and is also included in the damage indicators. Normalised results are presented, comparing each scenario with the highest-impact scenario for each indicator, and the latter is assigned a value of 100%. No ponderation is applied to the damage categories to aggregate under a unique score for each damage impact indicator. The greater the normalised results, the greater the potential impacts, therefore, the smallest normalised results should be prioritised.

Outfitter hospitality services perspective

From the outfitter hospitality services perspective, the status quo scenario based on fossil fuels defines the baseline for the system definition (step 1) and decomposition (step 2). Three additional scenarios (Table 8) combining renewable and fossil fuel energy alternatives are evaluated using LCA indicators. Only the energy source and energy equipment needed to deliver the same outfitter bundle services analysed in step 2 are evaluated (Table 4). Scenario configuration is based on key

² Although considered important to analyse in the context of renewable energy use, the long-term freshwater ecotoxicity midpoint indicator was excluded from ecosystem quality damage category because it is overestimated. The metal emissions in the groundwater compartment has not been determined and the LCIA methods encounter limitations (See toxicity and ecotoxicity – metal emission in groundwater at https://www.impactworldplus.org/version-2-0/#elementor-toc_heading-anchor-3).

eco-efficiency tourism factors from Teigeiro et al. (2025), including the quantity of products and services (affluence), defined by the estimated quantity of energy at 209 GJ for the baseline, as well as the technology used (resources and equipment). For example, switching from propane to electric kitchen equipment enhances efficiency and reduces dependence on fossil fuels, thereby altering total energy requirements for the same level of service. Modular strategies in this case involve swapping energy sources and equipment modules, keeping others constant. The outfitter hospitality services system's function for the LCA approach is to provide energy needs for a typical high season (May to September) with an average occupancy of 74%, based on 2022 data.

The outfitter hospitality services alternatives section in Table 9 presents annual results for each energy scenario, illustrating the results by colouring the cells from green, yellow, to red from the best to the worst results. In the current status quo, annual energy consumption contributes to 0.13637 years of healthy life lost due to disease or health conditions (DALY) (World Health Organization, 2020) and the potential disappearance of all species in 33,986 m² over a year (m² PDF.m².yr). Over 50 years, this totals 6.8 DALY and irreversible damage to the same land area. Scenario 1, based on renewable energy, improves performance in terms of human health and ecosystem quality damage by 71% and 84%, respectively, compared to the status quo. Scenarios 2 and 3, both composed of 2/3 propane and 1/3 of renewable energy, perform similarly, with Scenario 3 slightly better (5% for human health and 3% for ecosystem quality).

Problem-related impacts indicate that the outfitter status quo profile performs poorly compared to others; it emits 30,589 kg CO₂ eq annually (climate change, short) and contributes to 388,220 MJ deprived from energy consumption (fossil and nuclear energy use). Scenario 1 cuts these impacts by 84% and 85%, respectively. However, it leads to an increase in mineral resource use, with 131.34 kg of depleted mineral resources, primarily due to the materials used in batteries and wind turbines. Scenario 2 improves mineral resource use performance by 20%, while Scenario 3 improves it by 82%, compared to Scenario 1. The status quo presents the lowest impact, with 14,849 kg of resources being deprived, which is 89% better than Scenario 1.

The main contributing processes (details in the SUPPORTING INFORMATION section) vary by Scenario. For fossil-based scenarios (status quo, 2, and 3), diesel and propane combustion and production, as well as battery production and solar panel production, dominate human health, ecosystem quality, and climate change (short-term) issues. In contrast, the key contributors to Scenario 1 are the production of batteries, solar panels, wind turbine, and concrete block. For mineral resources, the production of wind turbines, concrete blocks, and batteries has the most significant impact in Scenarios 1 and 2, propane and battery production currently dominate the status quo. Propane and diesel production are the primary contributors to fossil energy use in scenarios that rely on fossil fuels. In contrast, Scenario 1 is primarily influenced by solar panels, batteries, wind turbines, and concrete block production, despite having the lowest overall impact for this indicator.

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Table 8 Outfitter hospitality services_energy technology profiles scenarios

Scenarios	Energy technology profile scenarios	Annual energy requirements (GJ)	Capacity (person.day)	Occupation rate	Description
Status quo	99 % fossil fuels (diesel, propane)	209	2 310	74%	2 stars. Accommodation basic amenities: service components such as housekeeping [sheets cleaning], lighting, heating, drinkable running water, hot water, waste management, internet, fire camp. Restaurant: food preparation, cooking, storage, cleaning.
Scenario 1	92 % renewable mix (50 % solar and 50 % wind)	74			
Scenario 2	68 % propane, 32% renewable mix (50 % solar and 50% wind)	140			
Scenario 3	68 % propane, 32 % solar	140			

Table 9 Perspective module alternatives damage and midpoint impact indicators

		Outfitter hospitality services alternatives				Tour operator alternatives					Transportation to site options (round trip, normalised %)		
		(annual, normalised %)				Hospitality services options (person.night, normalised %)					Option 1		Option 2
		Statu quo	Scenario 1	Scenario 2	Scenario 3	★2	★2	★2	★2	★1			
Damage impacts on AoP	Units	annual, (normalised %)				Deluxe Standard	Deluxe Green	Deluxe Innovation	Deluxe Transition	Basic Cottage	Round trip, (normalised %)		
Human health	100000 DALY	13637 (100%)	3922 (29%)	6787 (50%)	6165 (45%)	7.9 (100%)	2.3 (29%)	4.0 (50%)	3.6 (45%)	0.9 (11%)	677 (40%)	1673 (100%)	
Ecosystem quality*	1 PDF.m ² .yr	33986 (100%)	5416 (16%)	14077 (41%)	12993 (38%)	19.8 (100%)	3.2 (16%)	8.2 (41%)	7.6 (38%)	1.5 (7%)	818 (100%)	619 (76%)	
Climate change, short term	1 kg CO2 eq (short)	30589 (100%)	4870 (16%)	12901 (42%)	11999 (39%)	17.8 (100%)	2.8 (16%)	7.5 (42%)	7.0 (39%)	1.8 (10%)	1416 (100%)	578 (41%)	
Fossil and nuclear energy use	0.1 MJ deprived	38822 (100%)	5881 (15%)	24924 (64%)	24117 (62%)	22.6 (100%)	3.4 (15%)	14.5 (64%)	14.1 (62%)	2.5 (11%)	2077 (100%)	1027 (49%)	
Mineral resources use	1000 kg deprived	14849 (11%)	131341 (100%)	105158 (80%)	24184 (18%)	8.7 (11%)	76.5 (100%)	61.3 (80%)	14.1 (18%)	0.7 (1%)	600 (58%)	1026 (100%)	

Legend
 Absolute values highlighted with red, yellow and green for worst to best results, with midpoint percentile at 50
 Impact indicators reflect IMPACTWorld+ midpoint level indicators
 *Excludes freshwater ecotoxicity, long term from ecosystem quality damage category.

Tour operator tourism package perspective

From the tour operator's perspective, designing sustainable tourism package scenarios requires integrating sustainability assessments from individual service modules. These assessments are dependent on supply chain data provided by upstream suppliers. This perspective enables the demonstration of module reusability across different service modular architectural levels. This is made possible through standardization and the use of functional conversion units, such as person.night. In this context, the life cycle assessment (LCA) results obtained from the outfitter hospitality services (described in the previous section) are reused as proxies to represent accommodation options within tourism package scenarios.

The tourism package module is composed of two (2) service modules: 1) five (5) outfitter hospitality options, ranging from a basic cottage to various forms of deluxe installations with distinct energy profiles, detailed under the description sheet (Table 6), and 2) two transportation options to the site (Réservoir Gouin) originating from Montreal, either by car and helicopter (option 1) or by car and boat (option 2) (Table 7). The environmental performance of these modules was evaluated through LCA (Table 9), and the results are expressed in both absolute and normalized terms (package.year and person.night) to support comparative analysis at both the system and individual levels. This standardization allows module results to be reused across multiple package configurations within the service modular architecture levels. It also ensures comparability across scenarios that differ in duration, group size, or module composition. These modules were then combined into twenty-five (25) distinct tourism package scenarios, organized into five (5) groups that each reflect the application of a specific eco-efficiency factor explained later: resource efficiency, volume, technology, duration, and frequency (Table 10). The scenarios also apply four (4) modular strategies in their construct: swap, remove, add and reuse modules. These factors and strategies enable the examination of how variations in package composition influence environmental performance.

The tourism package unit of comparison is defined as delivering an experience for a group of up to four (4) persons during the high season (May to September 2022). The outfitter hospitality services functional unit of providing energy needs for an average person.night was used in addition to the transportation module functional unit of transporting passengers from Montreal to the Outfitter site at the Réservoir Gouin by car, boat or helicopter. As part of the LCA limitations, the results do not reflect the equivalence between the modules based on secondary functions, such as the additional services that consume energy in Deluxe hospitality services compared to Cottage.

LCA results (section entitled Tour operator alternatives in Table 9, expressed in person.night) indicate variations in environmental performance across outfitter service options. In terms of human health impact, the Deluxe Standard option was found to be the most impactful (0.000079 DALY per person.night), whereas the Basic Cottage was the least (0.000009 DALY), representing an 89% reduction. The Deluxe Green option (0.000023 DALY), which prioritizes renewable energy use, outperforms both the Deluxe Transition and Deluxe Innovation options by 16% and 21% (0.000036 and 0.00004 DALY), respectively. Similar trends were observed for other indicators such as ecosystem quality, climate change (short-term), and fossil and nuclear energy use. However, for the indicator of mineral resource use, the Basic Cottage has the lowest impact (0.0007 kg deprived per person.night). At the same time, the Deluxe Green option, despite its renewable energy profile, resulted in the worst impact due to the material intensity of renewable

technologies (as presented earlier as outfitter hospitality services scenario 1). The transportation module results (second part of section Tour operator alternatives in Table 9) also reveal trade-offs between module options. Option 1 (car and helicopter transportation) produces 60% less human health impact and 42% lower mineral resource use than option 2 (car and boat transportation) per round-trip.vehicle. Conversely, option 2 is more favourable for ecosystem quality (24% lower impact), climate change (59% lower), and fossil energy consumption (51% lower). Supporting information 2 details a sensitivity analysis demonstrating that increasing transport efficiency with greater occupation rates improves the impact performance per person.

In Table 10, the twenty-five (25) tourism package scenarios combine the module options into five scenario groups, each testing one eco-efficiency factor. Scenario group 1 serves as the baseline (4 persons, 4 days, car and boat transport). Group 2 explores volume reduction by halving the group size to 2 persons, while Group 3 focuses on changing transportation technology. Group 4 tests the effects of extending the trip duration to twenty-one (21) days, while Group 5 examines the cumulative impacts of increasing trip frequency to twice a year. Across these groups, modular strategies, such as swapping, removing, or reusing modules, are employed to assess their impact on environmental performance. The upper part of Table 10 presents results per package.year and the lower part presents results per person.night.

Key trends emerge from the scenario analysis based on package.year. First, as seen in the previous results, incorporating renewable energy in accommodations and reducing consumption generally improves environmental performance across most indicators. However, it often increases mineral resource use due to the embedded impacts of low-carbon technologies. This trend is also reflected in scenario analysis with person.night unit. Mineral resource use is lowest in scenario groups 1 (statu quo), 2 (volume) and 3 (transport technology), with a performance ranging between 70% and 92%, resulting in improvements of between 7% and 70% compared to the worst scenario groups 4 (duration of trips) and 5 (increased frequency of packages consumed). The more renewable energy is used, the more mineral resources are negatively impacted, which comes with extended and repeated trips. Second, scenario group 5 (frequency) generally has the worst performance range across indicators.

In contrast, scenario groups 1 (baseline) and 2 (volume) offer the most stability, in terms of improvement range across indicators, with improvements ranging between 50% and 86%, compared to the worst scenarios across indicators. Between scenario groups 1 and 2, the results also indicate that a lower volume of persons allows a tourism package to perform slightly better, by an average of 6%. Third, scenario group 4 (duration) presents the broadest range of impacts, ranging from 0% to 85%, especially for mineral resource use. Fourth, scenario group 3 (transport technology) performs best overall for human health and mineral resource use indicators (between 50% and 63% and between 76% and 92% respectively, compared to the worst scenario). On the other hand, scenario group 3 performs less than scenario groups 1 and 2 for ecosystem quality, climate change (short-term) and fossil energy use indicators. Overall, the results indicate that selecting renewable energy options for an outfitter's hospitality services improves indicators, except for mineral resource use. Then, when comparing scenario groups, consumption patterns involving increased duration and frequency of trips generally have a more negative impact on indicators than other modular strategies. Impact assessments of tourism packages reflect product and service choices, and to ensure refined insights, per person.night results are also provided.

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When results are normalized per person.night, distinct trends emerge across the five scenario groups as they are compared on equivalent units. This approach has its limitations, which will be discussed later. First, scenario group 2 (volume) generally shows higher impact ranges across indicators and includes three of the worst-performing cases in terms of human health, ecosystem quality, and mineral resource use. Although this group achieves a 41% improvement in specific indicators compared to the overall worst-case scenario, its performance remains generally inferior to that of other scenario groups. Second, scenario groups 1 (baseline) and 5 (frequency) offer the most stability, in terms of improvement range across indicators, with improvements from 35% to 70% compared to the worst-case scenarios.

In contrast, scenario group 4 (duration) demonstrates the strongest range of eco-efficiency gains, achieving reductions of 59% up to 94%. Third, scenario group 3 (transportation technology) offers amongst the best results range for human health impacts and mineral resources use with improvements between 77% and 80% and 28% and 82% respectively, but holds the second-worst performance ranges for ecosystem quality improving results between 27% and 46%, and for climate change and fossil energy use with improvements of 0% to 15% compared to the worst scenarios for these indicators. Overall, low occupation rates tend to have a negative impact on results. While air transport can improve specific impacts, it also has adverse effects on others. Increasing duration improves the impact per person.night.

Attention was given to the transportation to site module, with two additional pieces of information. First, a representation of the transportation proportion within the tourism packages indicates that for 75% of tourism packages, more than 80% of impacts are attributed to the transportation to site module (Supporting information 2). Then, a sensitivity analysis (Table 11) confirms that vehicle occupancy has an influence on transportation impacts for a person.night unit. With four (4) passengers per vehicle, option 1 remains favourable for human health and mineral resource indicators. However, option 2 continues to perform better in terms of ecosystem and climate-related impacts. These findings reinforce the importance of optimizing group size and transport capacity when planning tourism packages. The results highlight that longer trips, fewer trips per year, and full occupancy rates are key strategies for improving tourism eco-efficiency.

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Table 10 Tour operator tourism package scenario impacts and damages (per package.year and person.night)

Per package year, normalised %		Modular strategies										3: Transport technology: Swap transportation to site**					4: Duration: Add hospitality services modules**					5: Frequency: Add tourist package **									
Eco-efficient factors (I = VABRP)	Parameters	1: Hospitality services energy technology: Swap hospitality services**					2: Volume: Remove hospitality services**					3: Transport technology: Swap transportation to site**					4: Duration: Add hospitality services modules**					5: Frequency: Add tourist package **									
		Group Standard	Group Innovation	Group Transition	Group Renewable	Group Rastic	Double Standard	Double Innovation	Double Transition	Double Renewable	Double Rastic	VIP group Standard	VIP group Innovation	VIP group Transition	VIP group Renewable	VIP group Rastic	Group Standard - long	Group Innovation - long	Group Transition - long	Group Renewable - long	Group Rastic - long	Double Standard x2	Double Innovation x2	Double Transition x2	Double Renewable x2	Double Rastic x2					
V	Volume (person)	4	4	4	4	4	2	2	2	2	2	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	2	2	2	2
A	Frequency (package per person)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2
B	Duration (days)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	21	21	21	21	21	4	4	4	4	4	4	4	4	4	4
Service component modules		Option 2					Option 2					Option 1					Option 2					Option 2									
P	Transport	Option 2	Option 2	Option 2	Option 2	Option 2	Option 2	Option 2	Option 2	Option 2	Option 2	Option 1	Option 1	Option 1	Option 1	Option 1	Option 2	Option 2	Option 2	Option 2	Option 2	Option 2	Option 2	Option 2	Option 2	Option 2	Option 2	Option 2	Option 2	Option 2	Option 2
P	Outfitter hospitality services	Deluxe Standard	Innovation	Transition	Deluxe Green	Basic Cottage	Deluxe Standard	Deluxe Innovation	Deluxe Transition	Deluxe Green	Basic Cottage	Deluxe Standard	Deluxe Innovation	Deluxe Transition	Deluxe Green	Basic Cottage	Deluxe Standard	Deluxe Innovation	Deluxe Transition	Deluxe Green	Basic Cottage	Deluxe Standard	Deluxe Innovation	Deluxe Transition	Deluxe Green	Basic Cottage	Deluxe Standard	Deluxe Innovation	Deluxe Transition	Deluxe Green	Basic Cottage
R	Damages on AoP	Units																													
	Human health	10000 DALY	1800 (50%)	1736 (48%)	1730 (48%)	1709 (47%)	1687 (47%)	1736 (48%)	1704 (47%)	1701 (47%)	1691 (47%)	1680 (47%)	804 (22%)	741 (21%)	733 (20%)	718 (20%)	693 (19%)	2340 (65%)	2005 (56%)	1974 (55%)	1865 (52%)	1749 (49%)	1009 (28%)	1412 (39%)	1396 (38%)	1379 (37%)	1246 (34%)	1213 (33%)			
	Ecosystem quality*	1 PDF m2.yr	936 (41%)	751 (33%)	740 (32%)	670 (29%)	643 (28%)	778 (34%)	645 (28%)	631 (28%)	1135 (50%)	950 (42%)	940 (41%)	869 (38%)	842 (37%)	1308 (57%)	1255 (55%)	884 (39%)	744 (33%)	1872 (82%)	1501 (66%)	1481 (65%)	1340 (59%)	1286 (56%)							
	Impact midpoints	Units																													
	Climate change, short term	1 kg CO2 eq (short)	867 (42%)	698 (34%)	689 (33%)	621 (30%)	608 (29%)	320 (15%)	638 (31%)	634 (31%)	600 (29%)	393 (19%)	1101 (52%)	1534 (74%)	1528 (74%)	1441 (70%)	1444 (70%)	1009 (48%)	1209 (58%)	1163 (56%)	816 (39%)	730 (35%)	1728 (83%)	1396 (67%)	1379 (66%)	1246 (60%)	1213 (58%)				
	Fossil and nuclear energy use	0.1 MJ deprived	1389 (47%)	1268 (43%)	1252 (43%)	1082 (37%)	1067 (36%)	1208 (41%)	1143 (39%)	1140 (39%)	1053 (36%)	1043 (36%)	2439 (83%)	2309 (79%)	2302 (79%)	2132 (73%)	2117 (72%)	2020 (100%)	2247 (77%)	2208 (75%)	1315 (45%)	1239 (42%)	2778 (95%)	2519 (86%)	2504 (86%)	2164 (74%)	2135 (73%)				
	Mineral resources use	1000 kg deprived	1165 (16%)	2007 (27%)	1252 (17%)	2211 (30%)	1038 (14%)	1095 (15%)	1516 (20%)	1139 (15%)	1638 (22%)	1013 (14%)	738 (10%)	1580 (21%)	823 (11%)	1824 (24%)	611 (8%)	1733 (24%)	612 (8%)	2210 (30%)	1088 (15%)	2668 (35%)	3974 (53%)	2954 (40%)	2661 (36%)	2100 (28%)					
R	Damages on AoP	Units																													
	Human health	10000 DALY	112 (52%)	108 (50%)	107 (49%)	105 (49%)	105 (49%)	105 (100%)	105 (49%)	105 (49%)	105 (49%)	105 (49%)	105 (49%)	105 (49%)	105 (49%)	105 (49%)	105 (49%)	105 (49%)	105 (49%)	105 (49%)	105 (49%)	105 (49%)	105 (49%)	105 (49%)	105 (49%)	105 (49%)	105 (49%)	105 (49%)	105 (49%)		
	Ecosystem quality*	1 PDF m2.yr	59 (60%)	47 (48%)	46 (48%)	42 (43%)	40 (41%)	40 (100%)	40 (41%)	40 (41%)	40 (41%)	40 (41%)	40 (41%)	40 (41%)	40 (41%)	40 (41%)	40 (41%)	40 (41%)	40 (41%)	40 (41%)	40 (41%)	40 (41%)	40 (41%)	40 (41%)	40 (41%)	40 (41%)	40 (41%)	40 (41%)	40 (41%)		
	Impact midpoints	Units																													
	Climate change, short term	1 kg CO2 eq (short)	54 (51%)	44 (41%)	43 (41%)	39 (37%)	38 (36%)	39 (85%)	39 (85%)	39 (85%)	39 (85%)	39 (85%)	39 (85%)	39 (85%)	39 (85%)	39 (85%)	39 (85%)	39 (85%)	39 (85%)	39 (85%)	39 (85%)	39 (85%)	39 (85%)	39 (85%)	39 (85%)	39 (85%)	39 (85%)	39 (85%)	39 (85%)		
	Fossil and nuclear energy use	0.1 MJ deprived	87 (57%)	79 (52%)	78 (51%)	68 (44%)	67 (44%)	68 (99%)	68 (99%)	68 (99%)	68 (99%)	68 (99%)	68 (99%)	68 (99%)	68 (99%)	68 (99%)	68 (99%)	68 (99%)	68 (99%)	68 (99%)	68 (99%)	68 (99%)	68 (99%)	68 (99%)	68 (99%)	68 (99%)	68 (99%)	68 (99%)	68 (99%)		
	Mineral resources use	1000 kg deprived	73 (34%)	128 (58%)	78 (36%)	141 (65%)	65 (30%)	117 (63%)	107 (67%)	107 (67%)	107 (67%)	107 (67%)	107 (67%)	107 (67%)	107 (67%)	107 (67%)	107 (67%)	107 (67%)	107 (67%)	107 (67%)	107 (67%)	107 (67%)	107 (67%)	107 (67%)	107 (67%)	107 (67%)	107 (67%)	107 (67%)	107 (67%)		

Legend
 Tourism package results midpoint percentile at 50 for coloured results from low (green) to high (red) impact per scenario group
 Impact indicators reflect IMPACTWorld+ midpoint level indicators
 Normalised results are based on the highest result which is given 100%.
 Values are influenced by changes in eco-efficient factors
 Units are given in the units in the table
 *Excludes freshwater ecotoxicity, long term from ecosystem quality damage category.
 **Module reuse, swap or addition included as modular strategies

Table 11 Transportation to site options sensitivity analysis

Damage impacts on AoP	Transportation to site options, Normalised results (%)					
	Option 1			Option 2		
	1 p.v	2 p.v	4 p.v	1 p.v	2 p.v	4 p.v
	Air and land transport, High speed			Land and water transport, Regular		
Human health	40%	20%	10%	100%	50%	25%
Ecosystem quality*	100%	50%	25%	76%	38%	19%
Impact midpoints	Units					
Climate change, short term	100%	50%	25%	41%	20%	10%
Fossil and nuclear energy use	100%	50%	25%	49%	25%	12%
Mineral resources use	58%	29%	15%	100%	50%	25%

Legend
 p.v : person.vehicle
 Tourism package results midpoint percentile 50 for shading results from low (green) to high (red) impact.
 Impact indicators reflect IMPACTWorld+ midpoint level indicators
 Normalised results are based on the highest result which is given 100%.
 *Excludes freshwater ecotoxicity, long term from ecosystem quality damage category.

Step 4_ Interpretation and decision-making

Decision-making related to scenario selection based on eco-efficiency performance involves complexity due to the numerous variables and factors at play. Structuring these elements through methodological tools can enhance the personalisation and effectiveness of actions. For example, normalisation helps elucidate subtle differences between scenarios, while the incorporation of sensitivity analysis enhances the robustness of decision-making processes. Following the framework proposed by Teigeiro et al. (2025), sensitivity analysis was integrated in the generation of eco-efficiency scenarios by introducing variations across key factors and modular strategies. From an outfitter's hospitality services perspective, this included evaluating alternative energy profiles. From the tour operator's perspective, variables such as group size, trip duration, transportation modes, occupancy rates, and outfitter hospitality services alternatives were considered. Interpretations and recommendations were formulated for each perspective based on the resulting environmental performance metrics.

At the level of outfitter hospitality services, scenarios integrating renewable energy sources performed better than those based on conventional fossil fuels (e.g., diesel, propane) in most impact categories, except for mineral resource use. When assessing outfitter hospitality service options from the tour operator's perspective, on a per person.night basis, findings corroborated these results, suggesting that resource-light service options such as a "Basic Cottage", which demand lower energy inputs, should be prioritized before transitioning to more energy-intensive renewable solutions. While Scenario 1 from the outfitter hospitality services demonstrated the greatest overall environmental benefits, trade-offs in mineral resource usage must be mitigated to prevent burden shifting. Specifically, the use of concrete blocks in wind turbine installations significantly contributed to mineral resource consumption. Exploring alternative materials, such as recycled minerals or concrete blends incorporating recycled glass, may help reduce this impact without compromising other environmental gains. Scenario 3 of the outfitter hospitality services emerges as a viable transitional option toward renewable energy adoption, offering significant reductions in environmental impacts. These recommendations are based on a 74% occupancy rate and are limited to three product-service bundle modules, along with their respective energy and equipment configurations. In terms of short-term climate impacts, these modules align with key operational components identified by Filimonau (2016) and Filimonau et al. (2011), indicating that accommodation operations account for between 70% and 85% of total greenhouse gas (GHG) emissions and therefore should be addressed. These scenario recommendations advocate for the implementation of renewable energy, but do not consider the alteration of landscape aesthetics through large-scale solar panel installations and their impact on the tourism experience. They also do not address the economic feasibility of such investments. Future work should consider financial analyses and the development of supportive instruments (e.g., subsidies, environmental taxation) to promote adoption. Additionally, investigating tourists' willingness to pay for more sustainable options, such as for this kind of tourism (outfitter), would further inform policy and market interventions.

From the tour operator's tourism package perspective, results vary depending on the unit of measurement used, either package.year or person.night. Analysing these units in isolation can lead to misinterpretations and rebound effects, highlighting the need for integrated assessments. The person.night metric allows for cross-scenario comparability on an individual basis but fails to capture aggregate effects as effectively as the package-year measure. For example, results based

on person.night unit may encourage longer duration trips, more frequent shorter trips, rather than fewer trips, potentially undermining sustainability goals. On a package.year basis, Scenarios 1 and 2 tend to outperform the least favourable options in Scenarios 4 and 5 across most indicators, suggesting that shorter trips with fewer travellers are generally more eco-efficient. However, when evaluated per person.night, Scenario 2 ranks among the least sustainable for three (3) out of four (4) indicators. Together, these results suggest that travelling in smaller groups with suboptimal occupancy is less efficient. Therefore, longer trips, higher occupancy rates, and transportation via car and boat (Scenario 2 option) appear preferable on a per person.night perspective, assuming a single annual trip between the study's fixed departure and destination points.

As the results demonstrate, transportation to the site accounts for more than 80% of the impacts in 75% of tourism packages, for most impacts, which is consistent with the literature. Energy use remains predominantly dominated by the transport industry in tourism, and the literature also suggests an increase in passenger load factors (Becken et al., 2003). Tour operators can positively influence tourism eco-efficiency in tourism supply chains by configuring tourism packages differently and incorporating improved eco-efficiency products and services (Sigala, 2008). Considering that 77% of revenues generated by halieutic tourism outfitters in Canada were through tourism packages in 2001 (Utovac, 2003), integrating this level of visibility through an ecolabel could improve a non-negligible proportion of this industry's consumption. From a broader urban and tourism planning standpoint, further investigation into the full life cycle impacts of transportation modes is warranted. A study conducted in France (de Bortoli & Féraillé, 2024) indicates that air travel has the highest environmental impact, followed by private car use, carpooling, coach travel, and high-speed rail, in descending order of environmental burden. Incentives to influence consumption should consider the factors demonstrated earlier. For instance, increasing the occupancy rates of vehicles should be considered in policies, as currently high season prices with high occupancy rates tend to be more expensive than travelling during the low season with lower prices, lower occupancy rates, but a greater environmental burden per person. On the other hand, local policies should also keep a close look at how visitor flow influences socioeconomics.

Overall, the findings suggest that to enhance eco-efficiency, tourism packages should aim to maximize occupancy, promote more extended trips only if traveling less often, and reduce the frequency of travel. The study excluded the point of origin of tourists, which could alter results, particularly for long-haul air travel. In 2001, international visitors (primarily from the United States of America) accounted for 64% of the clientele at Canadian outfitter and hunting sites, compared to 36% of domestic visitors (Utovac, 2003). Findings from Gössling et al. (2005) emphasize the importance of source markets in determining tourism sustainability, where long-haul travel deteriorates tourism's global average eco-efficiency, therefore, domestic tourism could yield more sustainable outcomes. The results further resonate with the "slow travel" movement, which promotes conscious travel in relation to sustainability issues, prioritises longer trips in fewer destinations to immerse oneself in the culture and experience, and within shorter distances of travel (Dickinson et al., 2011), thereby distributing travel-related impacts over more days. This movement only reduces overall impacts if travelling occurs less often. Although social impacts were not considered in this study, future research should evaluate the broader socio-economic implications of promoting longer and less frequent trips. In summary, the assessment highlights the inherent complexity in assessing the sustainability of tourism packages, given the multitude of interacting variables and perspectives. The present study offers

a structured approach to exploring these dynamics, recognizing that, from an environmental standpoint, the most sustainable travel scenario remains non-travel.

3. DISCUSSION

This study introduces a four-step systematic methodology for characterising tourism systems within a modular, multidimensional, and multiperspective modelling framework to support the assessment and standardization of sustainability and eco-efficiency information. The method facilitates a uniform framework definition across multiple perspectives, utilising consistent tools, templates, and modules, which enables the creation of diverse scenarios that inform eco-efficient decision-making. The cases of an outfitter hospitality service provider and a tour operator are used to demonstrate its multiperspective and flexible application.

The choice of modularity as the fundamental concept supporting both the framework and the method stems from the complexity of the tourism industry. It necessitates a comprehensive approach to assess and communicate its environmental footprint. The study further demonstrates that dividing a service system into standard components and configuring them in various ways improves both efficiency and performance (Voss & Hsuan, 2009) from a sustainability posture. It enables the more efficient use of standardised inputs and allows for a better understanding of how to improve energy efficiency, thereby improving environmental sustainability (Wehner et al., 2020). Without reusable results and factors to configure tourism scenarios, it is nearly impossible to claim that a tourism product, service, package, or other module performs environmentally better than another, especially considering the numerous variables that come into play. The method relies on modularity methods proposed in the literature, mainly in operational management and engineering contexts (de Mattos et al., 2021; Eissens-van der Laan et al., 2016; Groetsch et al., 2021; Gu et al., 1997; Spykman et al., 2021; Voss & Hsuan, 2009) and employs a service modular architecture to facilitate information transfer between perspectives and units of measurement. For example, accommodation-level metrics can be translated into a person.night equivalents to support package-level assessments and informed decision-making.

The method's application across two distinct tourism perspectives demonstrates external validity and reproducibility through a sequential and transparent four-step process. Methodological rigour is reinforced throughout the proposed steps, as evident in the explicit definition of modules and their interrelations. System decomposition, guided by an adapted service modular architecture, facilitates the management of complexity and the establishment of cross-perspective linkages, thereby supporting the application of modular strategies. This hierarchical organization clarifies interconnections within tourism supply chains. For example, modules developed from outfitter hospitality scenarios were subsequently reutilised or multiplied (modular strategies) within tour operator package scenarios, and the evaluation and selection of alternatives based on eco-efficiency performance.

Modular strategies, adapted from Eissens-van der Laan et al. (2016), further support the explicit identification of eco-efficiency factors within scenario development, thereby enhancing the capacity to design actionable and independent interventions. This facilitates accessibility for hospitality service providers seeking to improve the environmental performance of their services by exploring alternatives, such as energy source alternatives. Otherwise, tour operators may adjust packages through targeted modifications, such as substituting accommodation or transportation modules, or capturing tourism eco-efficiency factors influenced by consumption behaviour or preferences, for instance. The tour operator tourism package example enabled the identification of

twenty-five (25) alternative scenarios related to five (5) tourism eco-efficiency factors, each with two (2) units of measure, for a more thorough analysis. In addition to outcomes of specific scenarios, general trends were observed for the Outfitter stay and itinerary from Montreal to the Reservoir Gouin. Travelling in smaller groups with suboptimal occupancy is less eco-efficient. Whereas, for a single annual trip analysed, longer trips, land-based travel, and higher transportation occupancy rates were preferable per person.night basis. When considering results per package.year scale, fewer travellers, shorter trips and lower annual tourism package consumption appeared advantageous. Overall, these results suggest that less frequent travel, combined with high occupation rates and extended stays³ at hospitality service providers that utilise renewable energy and account for impact displacement, constitutes a more eco-efficient strategy. Notably, transportation accounted for the largest share of total impacts in the tourism package scenarios studied, highlighting that both transportation modes and their occupancy rates are determinants of tourism package eco-efficiency.

The iterative nature of the scenario creation step in the proposed method promotes continuous refinement and the extension of models through the operationalisation of the flexible and evolving modular modelling framework for tourism sustainability (Teigeiro et al., 2025). Among its advantages and utilities, the generality of the framework and method allows generalising the approach among multiple stakeholders, fostering multidisciplinary collaboration (Miller & Torres-Delgado, 2023). Such versatility expands the applicability of the method across different study objects within tourism systems. Furthermore, the methodological approach developed in this study addresses recent calls for a harmonized yet adaptable framework for sustainability assessment in tourism. Miller and Torres-Delgado (2023) emphasise that a global consensus on such a framework must incorporate flexibility to accommodate diverse regional and sectoral contexts. In contrast, Gössling et al. (2023) advocate for simplification and enhanced comparability of emissions accounting to strengthen collective learning among tourism stakeholders.

Despite the contributions of this study, several limitations and avenues for further development remain, particularly regarding the standardisation of the framework, methodological completeness, and practical applicability. Establishing modules as industry standards will require international consensus to ensure coherent application and broader adoption. The framework currently does not explicitly address uncertainty, sensitivity analyses are limited, variability across LCA methods is untested, and comparative studies involving additional perspectives are needed. The initial phases remain accessible to organizations and certification bodies, facilitating the structured identification of essential information. Nonetheless, stakeholder feedback is necessary to assess usability across varying expertise levels. While literature highlights the value of integrating multiple assessment tools, this study operationalized the framework solely through environmental Life Cycle Assessment (LCA), leaving its adaptability for complementary tools untested. Future research should explore diverse instruments to enhance methodological robustness, address additional sustainability dimensions, including social indicators (Miralles et al., 2024), and support more nuanced scenario analyses. The limited scope of this research did not include direct engagement with the Atikamekw Nation. Future studies in this region should actively collaborate with the Atikamekw, while also recognizing the broader importance of incorporating Indigenous Peoples in Canada and internationally. Integrating Indigenous governance systems and knowledge frameworks is essential for capturing socio-economic

³ Extended stays if traveling less often.

impacts, advancing community well-being, and strengthening the relevance and legitimacy of sustainability research. Addressing these limitations through broader testing, stakeholder engagement, and tool integration will be essential to strengthen the framework's robustness, adoption, and capacity to guide sustainable transformation in tourism systems.

Overall, the proposed methodology provides a systematic, reproducible, and flexible approach to modelling complex tourism systems, enabling multiperspective sustainability assessment and evidence-based, eco-efficient decision-making. By integrating modularity, scenario analysis, and cross-perspective linkages, the framework advances both theoretical understanding and practical tools for sustainable tourism management.

4. CONCLUSION

In conclusion, this research addresses the inherent complexity of the tourism industry, which has led to chaotic situations such as inconsistent sustainability interpretations, the use of a large number of assessment tools, challenges in modelling tourism systems and the proliferation of ecolabels. The latter are often characterized by irregularity, lack of transparency, and insufficient standardization, thereby complicating the identification of genuinely more sustainable offerings. To overcome these shortcomings, this study proposes a systemic and systematic methodology for characterizing a modular tourism system to enhance sustainability. Drawing on modularity concepts from information technology and engineering fields, this approach enables the decomposition of complex tourism systems into manageable, minimally interdependent modules. This facilitates a systematic evaluation and adaptation of eco-efficiency factors through flexible modular configurations.

The application of this modular framework from two distinct perspectives has demonstrated its versatility in modelling system modularity and configuring various eco-efficiency scenarios, with a primary focus on energy consumption. The study enables the isolation of modules, such as energy sources for accommodation services, which indicate that renewable energy sources generally outperform fossil fuel-based ones across most impact categories, with the notable exception of mineral resource use. The "Basic Cottage," a less energy-intensive option, emerged as a priority for energy efficiency amongst the alternatives identified. For tour operators, the analysis revealed that results vary depending on the unit of measurement used (package.year or person.night), underscoring the necessity of integrated assessments to avoid rebound effects that could counteract sustainability objectives. It also demonstrates how the use of factors and the application of modular strategies enable the influence of tourism package eco-efficiency performance. Overall, it is suggested that tourism packages should aim to maximize occupancy rates, promote extended trips, and reduce travel frequency to enhance eco-efficiency. The method offers a standardised and holistic approach for tour operators to evaluate tourism packages, which would otherwise be cumbersome (Filimonau, 2016).

Modularity is an asset for enhancing the reliability of ecolabels by fostering both standardization, flexibility and transparency. It not only facilitates the comparability and credibility of sustainability information but also enables the reusability of data and information transfer between different perspectives and modular architecture levels. This framework allows for the prioritization of key impact modules [such as accommodation and transport, which are tourism sustainability "hotspots" (Eijgelaar & Peeters, 2024; Sun et al., 2024; Tsai et al., 2014)]. It also supports informed decision-making by enabling the evaluation and comparison of different

modular configurations, guiding choices for consumers, suppliers, tour operators, and investors. The potential for extensibility of the modular framework beyond initial energy consumption to include other resource modules (e.g., natural, manufactured, cultural, social, and financial), product and service modules, indicators, and even evaluation tools demonstrate its versatility and capacity for comprehensive sustainability assessment.

This research makes an original contribution to the service design literature by proposing a flexible calculation framework to measure sustainability performance, modelling the tourism system through a multi-perspective and modular approach. It demonstrates the application of modularity for sustainability purposes in services, a domain where previous studies have mainly focused on benefits related to products. Despite its contributions, the study acknowledges certain limitations, notably challenges related to data availability and transparency. Establishing modules as industry standards will require consensus among researchers, labelling bodies, and practitioners. Future research should focus on fostering such alignment to support methodological harmonisation and reduce risks of misleading sustainability communications, such as greenwashing or greenhushing (Font et al., 2017). Future contributions will also need to explore the integration of complementary tools and more in-depth sensitivity analyses to fully validate the approach, and to incorporate economic and social dimensions. Nevertheless, this study offers a structured and adaptable approach for evaluating tourism sustainability, acknowledging that, while non-travel remains the most sustainable scenario from an environmental standpoint, continuous improvement of tourism eco-efficiency is imperative given the sector's ongoing growth.

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6. AUTHOR CONTRIBUTIONS WITH CREDIT ROLES

Sophie Bernard, Jean-Marc Frayret and Sarah Teigeiro: Conceptualisation, Resources, Writing – Review & Editing, Funding acquisition, Sophie Bernard, Jean-Marc Frayret: Supervision, Sarah Teigeiro: Methodology, Validation, Formal analysis, Investigation, Data curation, Formal analysis, Writing – Original Draft, Visualisation, Project administration. All authors approved the paper and agreed to its submission for publication.

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9. SUPPORTING INFORMATION

[Insert Supporting Information summary text here. See example.]

Supporting information 1

Supporting Information 1 provides insight into the contribution analysis for an outfitter hospitality services alternatives, focusing on the impact and damage categories analysed in the study.

Tourism Eco-Efficiency Through a Modular Lens

Figure supporting information 1.1 Contribution analysis for an outfitter hospitality services alternatives on Human Health (annual DALY)

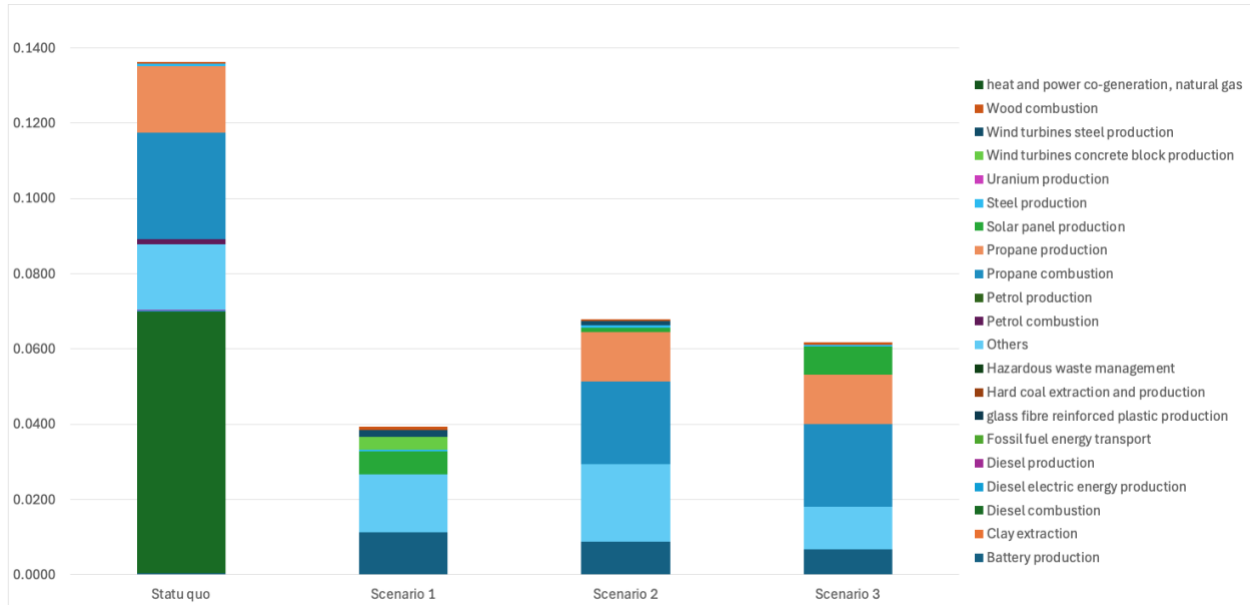
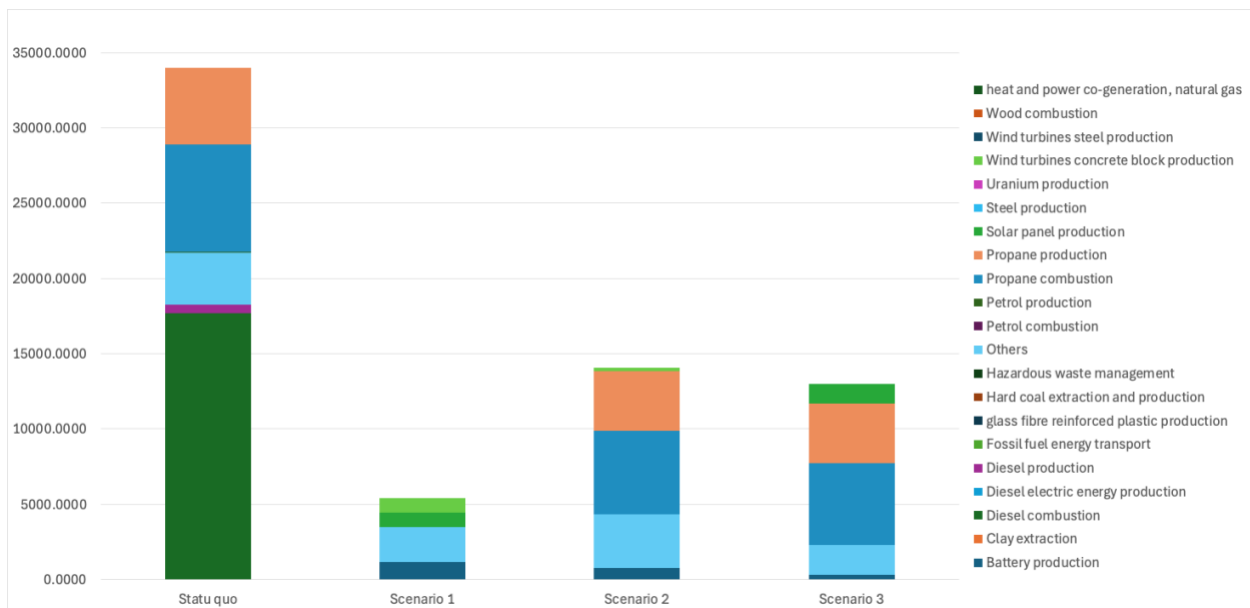


Figure supporting information 1.2 Contribution analysis for an outfitter hospitality services alternatives on Ecosystem Quality (annual PDF.m2.yr)



Tourism Eco-Efficiency Through a Modular Lens

Figure supporting information 1.3 Contribution analysis for an outfitter hospitality services alternatives on Climate change - short term (annual kg CO2 eq)

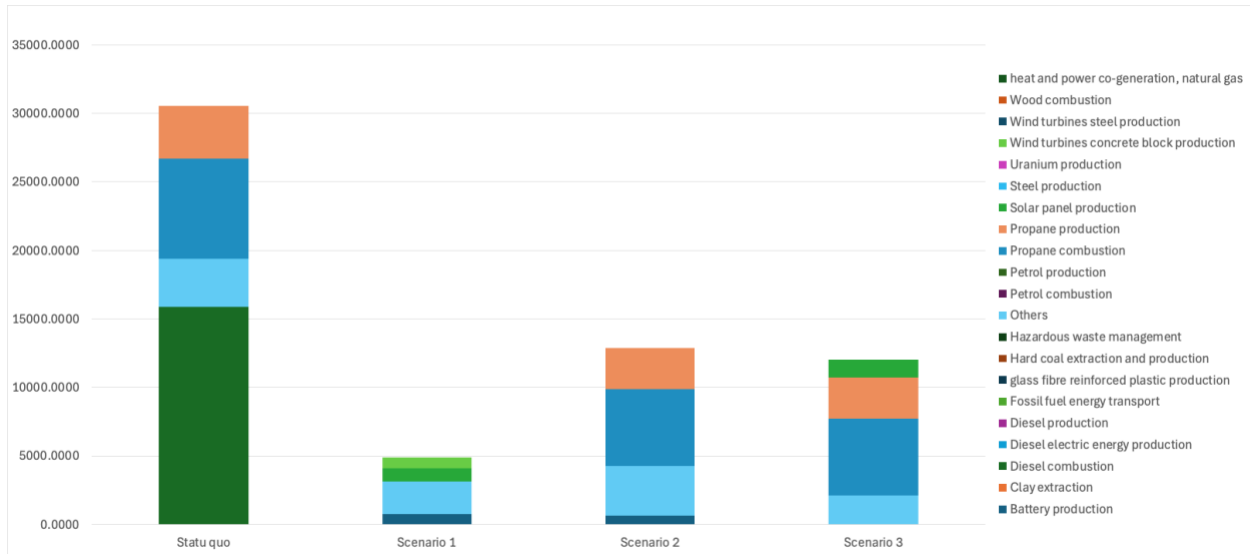
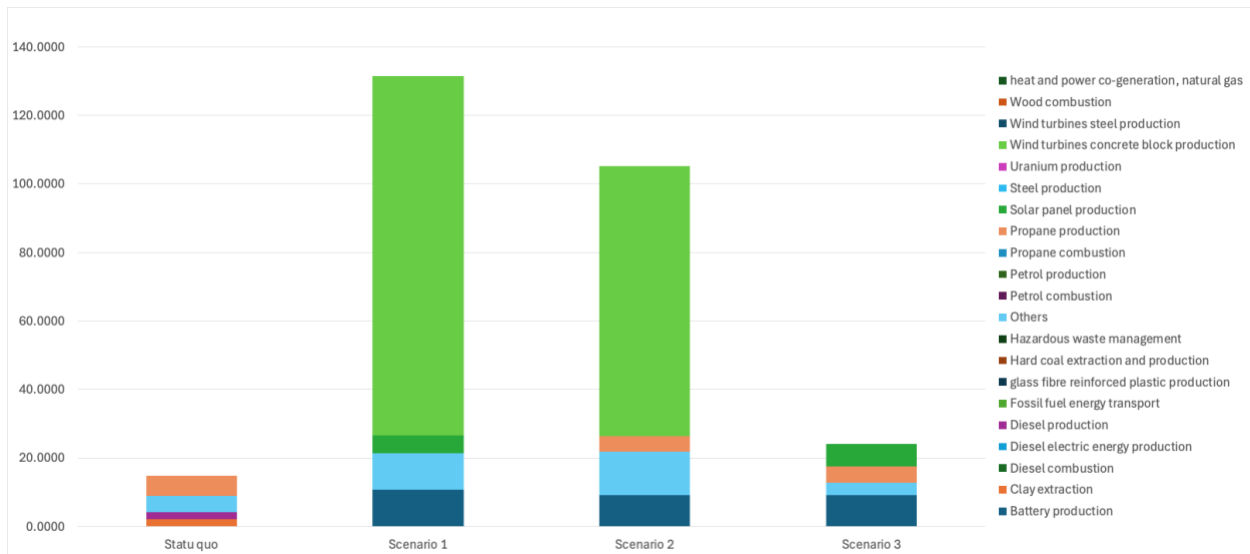
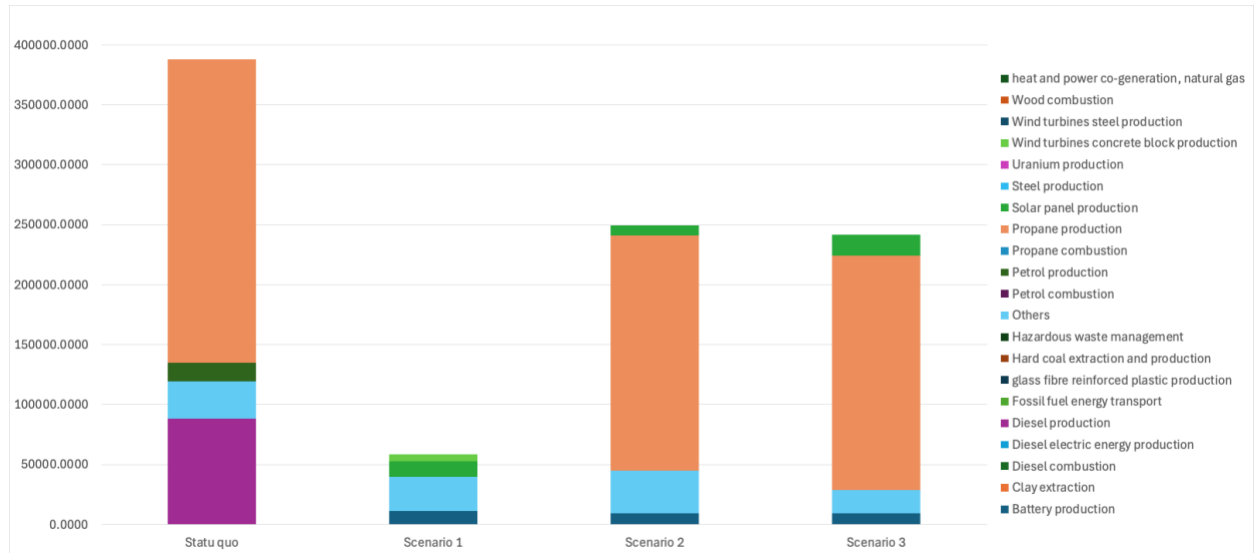


Figure supporting information 1.4 Contribution analysis for an outfitter hospitality services alternatives on Mineral resources use (annual Kg deprived)



Tourism Eco-Efficiency Through a Modular Lens

Figure supporting information 1.5 Contribution analysis for an outfitter hospitality services alternatives on Fossil and nuclear energy use (annual MJ deprived).



Tourism Eco-Efficiency Through a Modular Lens

Supporting information 2

Figure supporting information 2 Transportation to site contribution to tourism package (%)

Transportation to site contribution per package.year (%)		Modular strategies																																																		
Eco-efficient factors (I = VABRF)	Parameters	1: Hospitality services energy technology. Swap hospitality 2: Volume. Remove hospitality services**										3: Transport technology. Swap transportation to site**					4: Duration. Add hospitality services modules**					5: Frequency. Add tourist package**																														
		Group Standard	Group Innovation	Group Transition	Group Renewable	Group Rustic	Double Standard	Double Innovation	Double Transition	Double Renewable	Double Rustic	VIP group Standard	VIP group Innovation	VIP group Transition	VIP group Renewable	VIP group Rustic	Group Standard – long	Group Innovation – long	Group Transition – long	Group Renewable – long	Group Rustic – long	Double Standard x2	Double Innovation x2	Double Transition x2	Double Renewable x2	Double Rustic x2																										
V	Volume (person)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4																					
A	Frequency (package per person)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																					
B	Duration (days)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4																					
P	Service composited modules																																																			
P	Transport	Option 2 Deluxe	Option 2 Deluxe	Option 2 Deluxe	Option 2 Deluxe	Option 2 Basic	Option 2 Deluxe	Option 2 Deluxe	Option 2 Deluxe	Option 2 Deluxe	Option 2 Basic	Option 1 Deluxe	Option 1 Deluxe	Option 1 Transition	Option 1 Deluxe	Option 1 Green	Option 1 Basic	Option 2 Deluxe	Option 2 Deluxe	Option 2 Transition	Option 2 Green	Option 2 Basic	Option 2 Deluxe	Option 2 Deluxe	Option 2 Transition	Option 2 Green	Option 2 Basic	Option 2 Deluxe	Option 2 Deluxe	Option 2 Transition	Option 2 Green	Option 2 Basic																				
P	Outfitter hospitality services	Standard	Innovation	Transition	Green	Cottage	Standard	Innovation	Transition	Green	Cottage	Standard	Innovation	Transition	Green	Cottage	Standard	Innovation	Transition	Green	Cottage	Standard	Innovation	Transition	Green	Cottage	Standard	Innovation	Transition	Green	Cottage																					
R	Damages on AoP	Units	93%	96%	97%	98%	99%	96%	98%	98%	99%	100%	84%	91%	92%	95%	98%	71%	83%	85%	90%	96%	93%	96%	97%	98%	99%	66%	83%	84%	92%	96%	80%	90%	91%	96%	98%	72%	86%	87%	94%	97%	27%	47%	49%	70%	83%	66%	83%	84%	92%	96%
R	Human health	100000 DALY	66%	83%	84%	92%	96%	80%	90%	91%	96%	98%	72%	86%	87%	94%	97%	27%	47%	49%	70%	83%	66%	83%	84%	92%	96%	66%	83%	84%	92%	96%	80%	90%	91%	96%	98%	72%	86%	87%	94%	97%	27%	47%	49%	70%	83%	66%	83%	84%	92%	96%
R	Ecosystem quality*	1 PDF.m2.yr	66%	83%	84%	92%	96%	80%	90%	91%	96%	98%	72%	86%	87%	94%	97%	27%	47%	49%	70%	83%	66%	83%	84%	92%	96%	66%	83%	84%	92%	96%	80%	90%	91%	96%	98%	72%	86%	87%	94%	97%	27%	47%	49%	70%	83%	66%	83%	84%	92%	96%
R	Climate change, short term	1 kg CO2 eq	67%	83%	84%	93%	95%	80%	91%	91%	96%	98%	83%	92%	93%	97%	98%	28%	48%	50%	71%	79%	67%	83%	84%	93%	95%	67%	83%	84%	93%	95%	80%	91%	91%	96%	98%	83%	92%	93%	97%	98%	28%	48%	50%	71%	79%	67%	83%	84%	93%	95%
R	Fossil and nuclear energy use	0.1 MJ deprived	74%	82%	82%	95%	96%	85%	90%	90%	97%	98%	85%	90%	90%	97%	98%	35%	46%	47%	78%	83%	74%	82%	82%	95%	96%	74%	82%	82%	95%	96%	85%	90%	90%	97%	98%	85%	90%	90%	97%	98%	35%	46%	47%	78%	83%	74%	82%	82%	95%	96%
R	Mineral resources use	1000 kg deprived	88%	51%	82%	46%	99%	94%	68%	90%	63%	99%	81%	38%	73%	33%	98%	59%	17%	46%	14%	94%	88%	51%	82%	46%	99%	88%	51%	82%	46%	99%	94%	68%	90%	63%	99%	81%	38%	73%	33%	98%	59%	17%	46%	14%	94%	88%	51%	82%	46%	99%

Legend
 Tourism package results midpoint percentile at 50 for shading results from low (green) to high (red) impact per scenario group
 Impact indicators reflect IMPACTWorld+ midpoint level indicators
 Values influenced by changes in eco-efficient factors
 *Excludes freshwater ecotoxicity, long term from ecosystem quality damage category.
 **Module reuse, swap or addition included as modular strategies
 [Dotted square: Eco-efficient factor applied to scenario]