

**BANGOR UNIVERSITY**

**ENVIRONMENTAL IMPACT AND VALUE OF SEARCH ENGINES**

**FINAL REPORT**









## 2. OPPORTUNITY

The funding has enabled a systematic literature review of academic and non-academic reports on the environmental impacts and values of search engines. Ecosia ([www.ecosia.org](http://www.ecosia.org)) is a not-for-profit search engine company that dedicates 100% of its profits to the planting and protection of trees. By collaborating with local communities, it has planted more than 160 million trees all over the world. While a search engine that plants trees does have sustainability benefits, both Google and Microsoft search engines both do lots to make their operations more sustainable.

There is an opportunity for the University to contribute to tree-planting and restoration projects by making Ecosia the default search engine for all university campus computers,

The internet has transformed the way we live, work, and communicate and has become an integral part of our daily lives, with billions of people around the world using it to access information, connect with others, and conduct business. As the internet's popularity has grown, so too has its impact on the environment. The energy required to power data centres, networks, and personal devices has led to a significant increase in carbon emissions. Some estimates suggest that the internet and related technologies account for as much as 4% of global greenhouse gas emissions, a figure that is expected to grow as more people come online and digital technologies continue to evolve.

The environmental impact of the internet is complex and multifaceted and includes both direct emissions from energy use, such as electricity consumption by data centres and network infrastructure, as well as indirect emissions from the production and disposal of devices and the impact of online activities such as e-commerce and social media. Search engines, which are utilized daily by most internet users, can have substantial negative environmental impacts. Search engines constitute 93% of all web traffic and 5.06 billion people use search engines that process approximately 2.2 trillion search queries annually.

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<sup>1</sup> <https://www.businessdit.com/search-engines-usa-usage-statistics/>

## 3. ANALYSIS

### 3.1 SEARCH ENGINES

Performing massive amount of different search queries necessitates operating many ~~centres~~ ~~data~~ centres equipped with powerful computing hardware which requires significant energy consumption. This issue was





Table 1 t Description of novel search engines

Search Engine	Release Date	Focus	Key Features	Social/Environmental Initiatives	Ownership	Funding Model
Ecosia	2009	Environmental Sustainability	Plants trees with ad revenue, 100% renewable energy for servers	Tree planting, reforestation projects	Public Benefit Corporation	Ad revenue
GreenMaven	2008	Environmental Sustainability	Results prioritized by environmental impact, news and resources on sustainable living	Ecofriendly lifestyle,		

Search Engine	Release Date	Focus	Key Features	Social/Environmental Initiatives	Ownership	Funding Model
Lilo	2015	Social and Environmental Causes	Allows users to support various causes with searches, ad revenue donated to chosen cause	Range of social and environmental initiatives	Cooperative	Ad revenue
Goodsearch	2005	Social Causes	Donates portion of ad revenue to user-chosen cause	Range of social causes, education, animal welfare	Private	Ad revenue
Blackle	2007	Energy Conservation	Uses black background to save energy, powered by renewable energy	Energy conservation, carbon emissions reduction	Private	Ad revenue
Ekoru	2019	Ocean Conservation and Carbon Offsetting	Donates majority of ad revenue to ocean conservation and carbon offsetting, carbon neutral servers	Ocean conservation, carbon offsetting projects	Public Benefit Corporation	Ad revenue
WolframAlpha	2009	Education and Knowledge Sharing	Computational search engine offering information on a wide range of topics	Educational resources, knowledge sharing	Private	Paid subscriptions

Search Engine	Release Date	Focus	Key Features	Social/Environmental Initiatives	Ownership	Funding Model
SearchScene	2020	Social and Environmental Causes	Donates majority of profits to user chosen social and environmental causes	Range of social and environmental initiatives	Private	Ad revenue



and environmental initiatives. For instance, University of Cambridge is campaigning along with many others.

It's also worth noting that Ecosia offers a tool called Ecosia Campus, which is specifically designed for educational institutions.

## 3.4 SEARCH PERFORMANCE

When comparing the performances of search engines, several factors come into play. Search engine performance refers to the effectiveness and efficiency of a search engine in delivering relevant search results to users. But also, the carbon impact is another importance metric that should be considered while comparing the performance search engines.

### 3.4.1 Carbon impact of search queries

In this section, we summarize the empirical findings. Figure 1 and Figure 2 shows the carbon impact of a basic and URL search. A basic search refers to a simple and straightforward search conducted using a search engine or search bar to find information on the internet. It is the most popular search type. For instance, typing and entering into Google is a basic search. On the other hand, A URL search refers to performing a search query within a specific URL or website. It involves entering specific keywords or phrases into the search bar provided by a website or within the URL itself to find relevant information within that particular website or webpage. For example, if you want to search with websites such as Amazon and ebay, you will be performing a URL search.

The findings indicate that Ecosia is the best search engine for basic searches as it has the least amount of carbon emission. It outperforms Yahoo, Google and even its environmentally friendly rival, Lilo. A basic search impact in Ecosia comes with 13% carbon reduction when compared to Google that has an emission of 0.192 gEqCO<sub>2</sub>. However, Ecosia's superior performance compared to Google and Lilo has better performance in this category. Nevertheless, Ecosia dominates the remaining alternatives (Bing, Qwant, DuckDuckGo etc). Given that internet users mostly conduct basic searches rather than URL searches, Ecosia's carbon impact is negligible due to its vast superiority in basic searches.

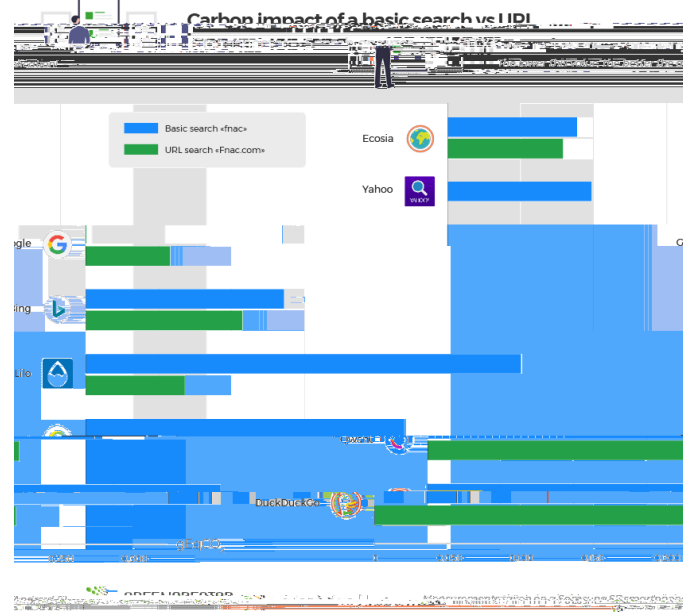


Figure 2- Carbon Impact of a basic search vs URL (source: Greenspector)

Local search refers to a search query that is focused on finding information, products, or services within a specific geographical location. The purpose of a local search is to help users discover businesses, events, or resources that are relevant and accessible within their immediate vicinity. For instance, if you want to explore the best Italian restaurants in Bangor, you can enter a search query into your search engine and easily obtain a list of popular Italian restaurants in Bangor.

Local search has become increasingly important with the rise of mobile devices and the growing emphasis on personalized and location-based experiences. Figure 4 shows the carbon impact of local searches. In this comparison, Ecosia, again, secures another victory with a wide margin. The carbon impact of local search engine is Ecosia (0.055 gEqCO<sub>2</sub>), indicating that using Ecosia instead of Google will lead to a 69% reduction in carbon emissions.

Weather searches refers to the act of using a search engine to obtain weather information for a specific location or to check the forecast for a particular region. It involves entering a search query related to weather conditions, such as the name of a city or a specific location, along with the term "weather" or "forecast," to retrieve the current or future weather details. For instance, you can type "London weather" and quickly obtain the weather conditions for London. Figure 5. In terms of weather search, Ecosia (0.062 gEqCO<sub>2</sub>) ranks 2nd after Lilo. Google is ranked as the third worst search engine, underperforming with a significant margin. Figure 6 demonstrates the performance of search engines for weather search.

Figure 3-





A basic definition search involves utilizing a search engine to discover the definition or significance of a specific wordphrase, or idea. This process entails inputting the term or phrase into the search engine's search bar to acquire a brief explanation or definition. When conducting a basic definition search, the search engine typically presents a direct answer or snippet at the top of the search results page, providing a brief definition or explanation of the term in question. This snippet is often extracted from a reliable and authoritative source. For instance, an engine can instantly obtain the definition. An example of a basic definition search is displayed in Figure 7 which also compares Google and Ecosia in terms of the accuracy of the search results. Since they both use Oxford Languages, they retrieve the same definition and yield an identical result. In Thi( Q0isthe43t)-3(ry08871 41)000881 41 both use Oxford Languages









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#	Google	Link	Ecosia	Link
1	CDC	<a href="https://www.cdc.gov/alcohol/fact-sheets/alcoholuse.htm">https://www.cdc.gov/alcohol/fact-sheets/alcoholuse.htm</a>	Alcohol Change	<a href="https://alcoholchange.org.uk/alcoholfacts/fact-sheets/alcoholandmentalhealth">https://alcoholchange.org.uk/alcoholfacts/fact-sheets/alcoholandmentalhealth</a>
2	Mental Health	<a href="https://www.mentalhealth.org.uk/explore-mentalhealth/a-z-topics/alcoholandmental-health">https://www.mentalhealth.org.uk/explore-mentalhealth/a-z-topics/alcoholandmental-health</a>	NHS	<a href="https://www.nhs.uk/conditions/alcoholmisuse/risks/">https://www.nhs.uk/conditions/alcoholmisuse/risks/</a>
3	NHS	<a href="https://www.nhs.uk/conditions/alcohol-misuse/risks/">https://www.nhs.uk/conditions/alcohol-misuse/risks/</a>	Mental Health	<a href="https://www.mentalhealth.org.uk/exploremental-health/a-z-topics/alcoholandmental-health">https://www.mentalhealth.org.uk/exploremental-health/a-z-topics/alcoholandmental-health</a>
4	Alcohol Think Again	<a href="https://alcoholthinkagain.com.au/alcoholyour-health/alcoholandlong-term-health/">https://alcoholthinkagain.com.au/alcoholyour-health/alcoholandlong-term-health/</a>	IAS	<a href="https://www.ias.org.uk/wp-content/uploads/2020/12/Thephysicalandmental-health-effects-of-alcohol.pdf">https://www.ias.org.uk/wp-content/uploads/2020/12/Thephysicalandmental-health-effects-of-alcohol.pdf</a>
5	American Addiction Centres	<a href="https://americanaddictioncenters.org/alcoholism-treatment/mental-effects">https://americanaddictioncenters.org/alcoholism-treatment/mental-effects</a>	Drink Aware	<a href="https://www.drinkaware.co.uk/facts/health-effects-of-alcohol/effects-on-the-body/alcoholandthe-brain">https://www.drinkaware.co.uk/facts/health-effects-of-alcohol/effects-on-the-body/alcoholandthe-brain</a>
6	Priory Group	<a href="https://www.priorygroup.com/blog/theshort-and-long-term-effects-of-alcoholconsumption-on-the-body">https://www.priorygroup.com/blog/theshort-and-long-term-effects-of-alcoholconsumption-on-the-body</a>	Health.com	<a href="https://www.health.com/condition/alcoholism/effects-of-alcoholon-the-brain">https://www.health.com/condition/alcoholism/effects-of-alcoholon-the-brain</a>
7	nidirect	<a href="https://www.nidirect.gov.uk/articles/how-alcohol-affects-your-health">https://www.nidirect.gov.uk/articles/how-alcohol-affects-your-health</a>	Webmd	<a href="https://www.webmd.com/mental-health/addiction/what-to-know-about-alcoholand-mental-health">https://www.webmd.com/mental-health/addiction/what-to-know-about-alcoholand-mental-health</a>
8	Webmd	<a href="https://www.webmd.com/mental-health/addiction/addictionheavydrinking">https://www.webmd.com/mental-health/addiction/addictionheavydrinking</a>	NHS	<a href="https://www.nhs.uk/live-well/alcohol-advice/therisks-of-drinking-too-much/">https://www.nhs.uk/live-well/alcohol-advice/therisks-of-drinking-too-much/</a>
9	Alcohol Change	<a href="https://alcoholchange.org.uk/alcoholfacts/fact-sheets/alcoholandmentalhealth">https://alcoholchange.org.uk/alcoholfacts/fact-sheets/alcoholandmentalhealth</a>	BUPA	<a href="https://www.bupa.co.uk/newsroom/ourviews/alcoholandmentalhealth">https://www.bupa.co.uk/newsroom/ourviews/alcoholandmentalhealth</a>





Alternative #2

Another option for Bangor University is to adopt an alternative search engine that promotes sustainability and sustainability and

## APPENDIX A SELECTED LITERATURE

Report title	Year & URL	Academic / Non academic	Search engines discussed	Main findings
The environmental impact of search engines apps	2020 <a href="#">Link</a>	Non-academic	Bing, DuckDuckGo, Ecosia, Google, Lilo, Qwant, StartPage and Yahoo	<p>x Ecosia outperform Google in basic search, weather search and local search and basic definition search</p> <p>Compared to other engines, Ecosia has a very low carbon impact, often ranking in the top or second place</p>
Every Google search results in CO2 emissions. This realtime data viz shows how much	2018 <a href="#">Link</a>	Non-academic	Google	<p>x By handling 3.5 billion search queries per day, Google is globally responsible for approximately 40% of the total carbon emissions attributed to the internet.</p> <p>With an approximate average of 47,000 requests per second, the platform generates an estimated 500 kg of CO2 emissions every second.</p>
Green Search Engine Usage: A Qualitative Study Exploring Why German				

Report title	Year & URL	Academic / Non academic	Search engines discussed	Main findings
The Carbon Footprint of Search	2023 <a href="#">Link</a>	Non-academic		



## APPENDIX B FUTURE OF SEARCH ENGINES

The rise of Artificial Intelligence (AI) chatbots is set to have a profound impact on the future of search engines as evident by the fact that ChatGPT becomes the fastest growing application of all time<sup>10</sup>.

These intelligent conversational agents transform the way users interact with search engines and revolutionize the search experience in several ways:

1. **Improved user engagement:** AI chatbots enable more interactive and conversational search experiences. Instead of relying on traditional keyword-based queries, users can engage in natural language conversations with chatbots to express their needs more precisely. This enhances user engagement and encourages a deeper exploration of search topics, leading to a more satisfying and informative search experience.
2. **Personalized and contextualized results:** AI chatbots can leverage user preferences, browsing history, and contextual information to provide personalized search results. By understanding the user's intent, chatbots can refine search queries, ask clarifying questions, and tailor the search results to match individual needs. This personalized approach ensures that users receive more relevant and contextually appropriate information.
3. **Natural language understanding and assistance:** AI chatbots are equipped with advanced natural language processing capabilities, allowing them to understand and interpret user queries more effectively. These chatbots can comprehend complex language structures, handle ambiguous queries, and extract meaning from unstructured data. By offering accurate and comprehensive responses, they enhance the search engine's ability to understand user intent and deliver precise results.
4. **Intelligent recommendations:** AI chatbots can provide intelligent recommendations based on user preferences and behaviour. By analysing user interactions and historical data, chatbots can suggest relevant search queries, related topics, or even recommend products and services. These personalized recommendations enhance the overall search experience, offering users valuable insights and saving time in the search process.

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<sup>10</sup> <https://www.reuters.com/technology/chatgpt-sets-record-fastest-growing-user-b-7fu>

5. Conversationalcommerce: AI chatbots have the potential to transform search engines into powerful platforms for conversational commerce. By integrating with commerce systems, chatbots can assist users in product searches, provide recommendations, answer questions about products or services, and even facilitate transactions directly within the chat interface. This

It is important to note that while AI chatbots offer numerous benefits, they also pose challenges related to privacy, data security, and ethical considerations. Safeguarding user data, ensuring transparency in decision-making processes, and addressing potential biases are critical aspects that need to be carefully managed. Ongoing research and collaboration between AI developers, search engine providers, and regulatory bodies are necessary to establish best practices, standards, and guidelines for the ethical and responsible use of AI chatbots in search engines. By addressing these challenges, search engines can harness the potential of AI chatbots while upholding user privacy, transparency, and fairness, ensuring that the future of search engines is not only innovative but also socially beneficial.