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Life cycle assessment of small hydro power plant:

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A B S T R A C T

Power production life cycle assessments (LCAs) are being improved to incorporate more precise temporal and geographical data, making surveys and findings more reliable. This meta-analysis searched the 2009-2020 LCA literature for geographical, temporal, and temporal resolution improvements. We found such contributions and filled research gaps by reviewing publications from an initial review. Most research is done in Europe, the Southeast, and Latin America, therefore other areas may be understudied. Greenhouse gas emissions dominated effect categories, detracting from consequences that would benefit most from more detailed assessments that account for local environmental circumstances. Most research focuses on one region, however, examining the smallest temporal and geographical dimensions (site and hourly) may result in more efficient therapies that enhance environmental and economic consequences. LCA has developed more in-depth grid interaction assessments, impact characterization, and resource evaluation to meet demand. Higher-resolution geographical and temporal analysis might help us understand power production, the system, and the environment. Hydropower is a common renewable energy source. Shutting down a hydropower facility has environmental consequences. Hydropower processing routes are widely used and produced, but little is known about their environmental and health effects. This research uses RECIPE and CML to analyse the human and environmental costs of reservoir-based hydropower production systems in Europe's alpine and non-alpine areas. Human health, ecosystems, warming, acidity, and other ecological degradation are considered when classifying these costs.

1. Main text

LCA has evolved to focus more on the ecological effects of energy systems. The use of life cycle assessment (LCA) as a decision-making tool in energy policy is on the rise, but there are still open problems about how the findings should be applied in the context of the inherent uncertainty of the underlying assumptions in this dynamic and rapidly changing field. Life cycle outcomes have had an effect on the development of renewable energy in certain instances, leading to a greater understanding of power systems and sometimes even affecting policy choices. But these kinds of evaluations are hard to do because of how fast the industry moves, how powerful it is economically, and how creative it is, as well as how hard it is to predict where and when things will happen. Different regions have their own unique blends of electricity sources because to the wide variety of generating technologies used in the electric grid, which includes anything from nuclear through renewables to fossil fuels. The outcomes of an LCA are significantly affected by such distinctions. Our research suggests that LCAs of power production might benefit from more detailed geographical and temporal characterization. Our systematic review was meant to help us figure out what we know now and where more research is needed. To begin, elements like transportation demands, community distributions, and local environmental conditions are often overlooked in LCAs that do not account for spatial variation. Second, the outcomes of discounting are sensitive to the time horizons chosen, which may either exaggerate or downplay the importance of short-term costs and gains. Another factor that may affect the reliability of the findings is the investigation's chosen temporal resolution. The evaluation of land use and ecosystem impacts when choosing between energy investments are all examples of the importance of spatial and temporal information for the power sector. Better information and methods for electric LCAs have been suggested for in recent research. The availability and use of more data, as well as the use of computer science, especially Geographic Information System software, are all factors in the growth of LCA methods in energy research. Life cycle assessment (LCA) is a data-intensive field, yet energy research data is much less accessible than data from other fields due to ethical and security concerns, undesired exposure, and higher strain. Greater precision in space and time has not always been a staple of LCA analysis.

2. Methodology

Our systematic study follows earlier research to analyse spatiotemporal improvements in the electricity LCA technique over the last decade. Web of Science, Google Scholar, and major LCA journal websites were searched. Google Scholar was used to gather data since it gave the most complete list compared to Cross Ref, Publish or Perish, and individual journal website searches. One may utilise a Python-based web scraper that is hosted on GitHub to

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manage Scholar searches that yield 1,000 or more results. A Python script was developed to do a search in Scholar and extract relevant data, including the article's title, authors, publication year, abstract, journal, publisher, and URL. The script also noted the search terms that were used, the page number the article was located on, and the article's location on that page for further reference. The keywords used in the search were chosen to indicate whether or not geographical and temporal contexts were taken into account in assessments of the power industry. They were used instead of a more targeted search term list to guarantee that a wide range of publications would be sensitively considered. The latter tends to generate more applicable research, but it also tends to miss a larger proportion of the time. We used the words "spatial" and "temporal" to convey the goal of improving approach. Similarly, we anticipated that "electricity," "life cycle assessment," and "LCA" would all bring up a wide variety of relevant publications. We chose the term "life cycle assessment" because it is the most common and well-known (ISO and the UN both use it). Although the word "life cycle analysis" was not used, the term "LCA" is used in conjunction with other articles, therefore the term "LCA" would be used to encompass these articles as well. Specifically, we utilised the following keyword combinations (complete with commas and quote marks):

Life cycle analysis (LCA), spatial, and energy considerations;

LCA (life cycle assessment), electrical energy, time-based

Life cycle assessment (LCA)spatial-temporal analysis (STA), and electric power

LCA, electricity, GIS After screening, the results were as follows: The article's functional unit was electricity production; it contributed to spatial, temporal, or spatiotemporal LCA methodology; and it was published between Jan. 1, 2009, and Dec. 31, 2018.

2.1Manual data labelling

Once a list of possible relevant articles was made, it went through four steps of screening: initial, full text, methodological, and final. During the first round of curation, submissions that were clearly outside the call for papers' scope, did not meet the criteria based on their titles and abstracts, or were only available online were thrown out. Different out-of-scope articles didn't include LCA or electrical in the title or description, but had other topics. Initial screening revealed 558 responses, with 5,961 items eliminated; 145 seemed to have no URL; 5,816 were scope-related.

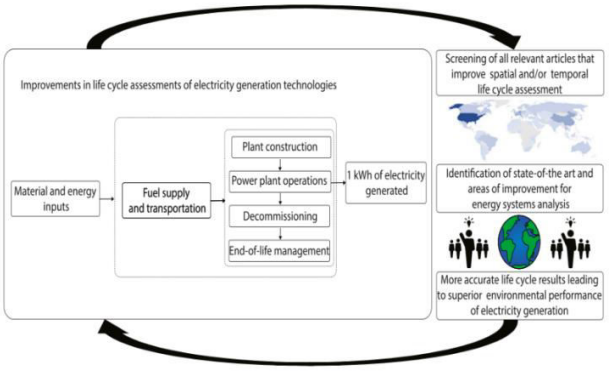

Fig-1. The paper's organisation demonstrates its significance to the economic structure in Wilson Joseph was able to design his own emblem for the people thanks to the Noun Project. The Earth image was retrieved from the Integration and Applications Network's media library (IAN.umces.edu/media-library) [1].

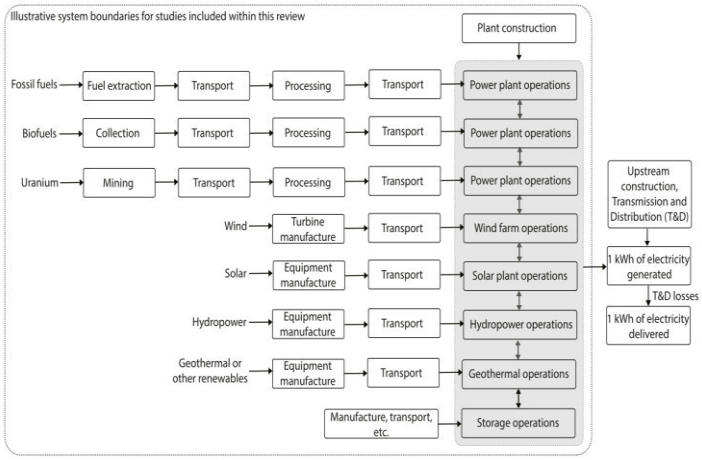

Fig-2 Our study offers a broad cross-section of the literature on power generation. That variety is rather normal, given that any LCA that examined two or more phases of the life cycle was considered for inclusion. Links between the grid & power plants are shown in grey. In our investigation, we could focus on a certain part of the system or examine the whole thing [4].

A comprehensive text review was then conducted to examine the findings for form and publishing suitability, with emphasis on life cycle evaluation and power production. Consistent with previous systematic evaluations of LCAs, we excluded PowerPoint presentations, entire books, and conference papers with less than five multi-page documents.

Articles of interest were located in anthologies and other collections of materials, removed, and finally

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stored in their original locations after checking for duplication. By using these kinds of criterion, we were able to cut the yield by 120. 45 results were discovered to be unavailable due to broken URLs, and were thus removed from further consideration. Lastly, 89 findings were eliminated because they were duplicated in other publications by excluding theses and dissertations. From the original text, we were able to pull out 304 different quotes.

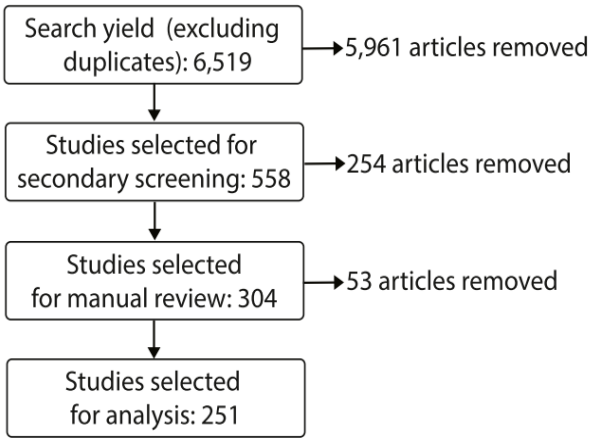

Fig-3. specifically, the method of elimination used for this analysis. After duplicates were eliminated, the remaining articles underwent a primary screening to weed out those that were irrelevant or incomplete. Additional honing was done by scope and publication type during the manual review [6].

Articles that met the inclusion criteria were classified as "Full Life Cycle Assessment," "Mixed Methods Research Incorporating LCA," "Non-LCA: Life Cycle," or "Other Relevant Analysis." The articles that used a mix of methods or fell into a category that wasn't LCA shed light on how the field might change in the future, while the "full LCA" publications show how methodological progress has been made through application.

Similar to other systematic assessments "whole LCA" indicated that the paper assessed the full life cycle, not just one phase (such as fuel supply and power production). So, the approach of this subcategory is similar to that of traditional systematic reviews. The information from the other three subcategories helps us learn more about the relevant literature. Articles labelled as "Mixed Methods Incorporating LCA" make explicit use of life cycle approaches to arrive at empirical findings without doing a complete LCA consisting of at least two life cycle stages. Articles that didn't follow conventional LCA practise included those that focused on only one stage of the life cycle, those that calculated costs without using LCA, and those that utilised LCA but didn't follow the guidelines. The research needed this category because the strict criteria of the "Full LCA" category would have stopped it from capturing unique implementations and meaningful improvements to life cycle methodology. Articles categorised as "Non-LCA: Other Relevant Analysis" did not use LCA methodologies and did not explicitly seek to advance them, but they made significant contributions to the discipline. Because "LCA" was a term that was used to find all of the articles in the review, these articles also discuss LCA. Consequently, their intended use and `items in terms of their direct relevance to LCA. The most marginalised subfield was kept in the end because its body of work is on the cusp of but not yet an integral element of the field's development.

2.2. Analysis

Select articles were classified in MAXQDA to examine their distribution over time, topics, regions, and method(s). The categories that were coded by hand were a

•The Year of Publication
•generation method for electricity
• primary focus on this system;
• a regional emphasis (continental-level nested codes leading to country-level codes)
• What kind of improvements were made to the way things were done •Applications of resolved data
•What is the LCA Method?
•How and when resolution is used

•Specific Impact Types

Finally, the collection of papers was combed through to find occurrences of the relevant phrases, such as impact characterization techniques databases and models (e.g., GREET). Observations were automatically tagged with the proper categories. In all, 9,957 distinct codes representing the articles were generated by the MAXQDA analysis. Finally, Excel was used to export the code data. All codes were converted to binary format inside Excel so that multiple occurrences of the same code within the same document would be counted as a single occurrence (see details). After taking these steps, we can now use the codes that our system automatically makes to tell if a certain phrase is in an Arctic article or not.

A comprehensive study of the articles, as well as an analysis of the coded articles, were conducted to determine the nature of the obtained methodological advancement. We were able to do this by conducting a comprehensive analysis of studies with the greatest possible spatial and temporal resolution to rank their significance (site and hourly) [8]. We then categorised all the articles we could find that included analysis models that might be employed with LCA into a

single master list. We analysed the articles to determine how frequently the two methods were discussed over time. This sheds light on how these analytical methods have influenced the development of integrated approaches. Then, we read articles that mentioned the most widely used analytics platforms to see if there were any takeaways that might be used to better LCA methods.[3]

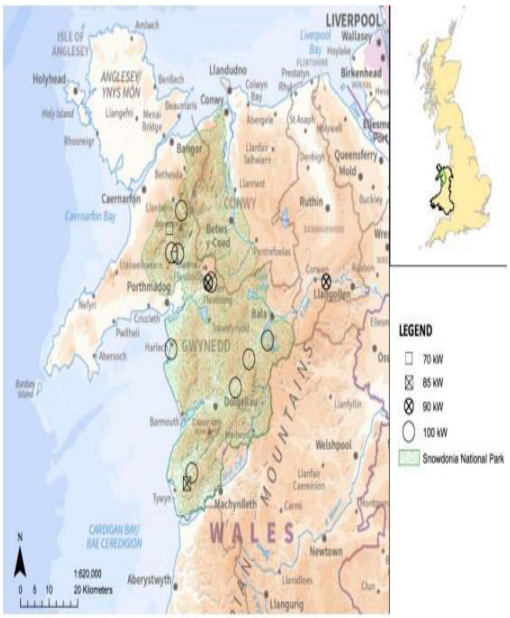

Fig-4. : These are the locations of the eleven micro-hydropower schemes that were analysed in the LCA research.[3]

3. Assessment and Discussion of Results:

3.1Classification of Articles and World Locations

Recent years have seen a rise in the number of articles published on this subject. Of the 251 articles that passed screening, 11 were released in 2008 and 32 in 2018. The category of Full LCA had an even more dramatic surge, going from 2 in 2012 to 15 in 2016, with 32 being the all-time high. However, the general trends are obscured by the sharp decline of publications in 2015 and the subsequent surge in 2016. Even though the number of Full LCAs has gone down, the number of "Mixed Methods" has gone up since 2015. As we go further into the articles, we can see that numerous causes contribute to the decline in publishing in 2015. To begin, in 2014, more submissions to the conference matched our criteria for acceptance. Second, in 2015, the Journal of Sustainability Consumption and Production was published. There was a surge in 2016 publications, which may have been caused by the two themed special issues published in the early half of the year. The 2013 version of Ecoinvent has been the subject of two studies in The International Review of Life Cycle Analysis[9].

We blame the time it takes to have a paper published (from first draught through peer review to final print). Finally, public debate and policies relating to the 2030 Agenda for Sustainable Development may have contributed to a significant drop in publications focusing on LCAs of coal. There were 140 references to biofuels in all papers, but only 79 in the full life cycle assessment category. There were 25 references to biofuels in the Mixed Methods category, 24 references to biofuels in the Non-LCA: LCA-Focused category, and 12 references to biofuels in the Non-LCA: Other Relevant Assessment category. Note that although most bioenergy research has focused on biofuels with and without CHP (100 and 10, respectively), other topics such as biogas with and without CHP (30 and 4), effluents (31), fuels (20), and foliar fuel cells (1) have also been investigated. If the characterization of energy production was a major input to the conversion and the outcomes were considered based on a unit of electricity, then biofuels were taken into account. Articles focusing on optimization and market integration solutions underlined how location may result in lesser environmental damages and improved economic performance due to the localised structure of feedstock supply chains, which was identified as a significant barrier to the scaling of bioenergy. There was a wide range of geographical scope in the 251 articles, from site-level analyses to cross-national and pan-regional surveys. The number of European occurrences came in at 373, the number of Asian occurrences at 136, the number of North American occurrences at 74, the number of South American occurrences at 45, and the number of African occurrences at 34. "Location" is an umbrella term for many different types of research topics, such as cities, subnational jurisdictions, regional areas that span multiple jurisdictions, and whole countries. [6]

The United States was mentioned 52 times in the selected publications, followed by Italy with 26, Germany with 24, Spain with 24, China with 22, and France with 22. (19). Coal was the most widely used fuel source in Germany, China, and France, whereas solar was the most widely used fuel source in the USA and Spain. Natural gas, biofuels, and oil are also widely used. COAL biomass to liquids (CBTL), fuel production (keeping in mind that hydrogen is often seen as an energy carrier instead of a fuel), peat, and tidal energy were the technologies with the lowest global penetration.[7]

Although fuels were explored at approximately constant rates across all articles across the studied time, our data suggests that full LCAs are now studying a wider variety of fuels than they were in 2009. Increasing occurrences of intermittent sustainable power and a more even dispersion of

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incidences across fuel types have been reported. We point out that for types of fuel with low publishing rates (like geothermal), yearly variation may be linked to the output of a few experts.

3.2 Resulting Classes

We made a list of the impact areas that were talked about in the "All Papers" and "Full LCAs" articles. Both kinds of papers we looked at showed an increase in the number of impact areas that had been researched over time. A total of 183 instances out of a possible 729 can be found in all 251 papers ("All Papers"), and 129 out of a possible 587 can be found in the 147 "Full LCAs," indicating that climate effects have gotten the greatest attention. In 2018, climate-related consequences were examined 10 times as often as acidity potential, human health, eutrophication potential, and resource shortages. After the first few categories, the remaining impact types see a precipitous reduction in their incidence rates. It's reasonable to assume that the 2007 Nobel Prize awarded to the Climate Change Intergovernmental Panel (IPCC) contributed to the increased focus on climate consequences in public discourse and financial support.

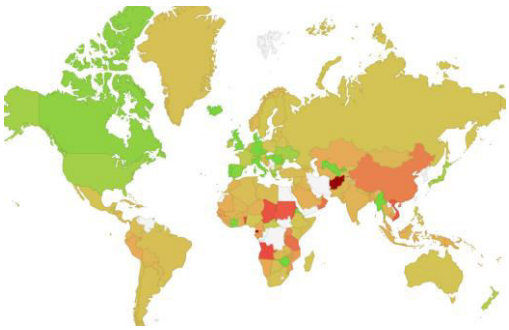

Fig5: Geographical variability [6].

3.3 Precision in both space and time

It is important to point out that our findings show that the time dimension has been ignored in favour of the geographical dimension. For instance, biomass was mentioned the most in both the "All Papers" and "Full LCA" categories, out of all the fuel types investigated. We found that sub-annual temporal scales had a similar number of events as some of the larger geographical scales we described. different energies (notably, coal, hydro, wind, solar, nuclear, and oil). The solar and wind publications were found to have the highest frequency of direct incorporation of temporal resolution (45%). It wasn't until 2016 that the word "intermittent" started showing up often while discussing renewable energy sources; before that, it was only mentioned once a year (except in 2010 and 2015). About a quarter of studies that looked at temporal resolution discussed either wind or solar power. When compared to the second most popular topic, fossil fuels (38%), bioenergy was the third most popular

4. Conclusion:

Our systematic evaluation looked at the years 2009–2018 to see whether there were any changes in the way spatial and temporal considerations were handled in life cycle assessments for electricity generation. Although there have been improvements, our findings indicate that certain issues have still to be addressed. These open questions provide experts a chance to make significant contributions to the area. As a result of these openings, there has been a rising tide of publications on the respective subjects, indicating a burgeoning of interest and input. Notably, there has been an increase in the publication of non-LCA and mixed methods studies in recent years, indicating that there may be contributions that have not yet been explicitly incorporated into a full LCA. In the time period we looked at, both the variety of fuels studied and the variety of impacts studied have grown.

Integration of an analytical tool has led to progress in LCA.Optimization and geographic information systems were found to be the most frequently used analytical methods across the publications we reviewed. When combined with LCA, these tools enhance the process in a number of significant ways. For instance, optimization may shed light on the ways in which the placement and hourly dispatch of power plants might affect the dynamics of the grid throughout the course of their lifecycle. When applied to LCAs, GIS-improved data and analysis, optimised grid interaction, and enhanced cost assessments will provide crucial insights for the most effective environmental solutions. Our research suggests that knowing where energy projects will be located beforehand may help with financial forecasting and payback estimates. Our screened sample shows a growing use of techno-economic analysis alongside LCAs, which suggests that both studies may also gain from the same improvements. Last but not least, the use of multicriteria decision analysis shows that improving LCA could affect the interpretation phase and the decision-making process.

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